DEPARTMENT OF

AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY.

L. L. FOSTER, Commissioner.

FIRST ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY OF TEXAS,

1889.

E. T. DUMBLE, F. G. S. A.,
STATE GEOLOGIST.

AUSTIN:
STATE PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

OFFICE OF COMMISSIONER OF AGRICULTURE,
INSURANCE, STATISTICS, AND HISTORY.
AUSTIN, TEXAS, May 1, 1890.

Hon. L. S. Ross, Governor of Texas:

DEAR SIR—I have the honor to submit herewith the First Annual Report of the Geological branch of this office. The scope of the Report is briefly stated in the letter of Prof. E. T. Dumble, State Geologist, accompanying this Report, and any remarks in addition thereto are deemed unnecessary.

The following is a summarized statement of the expenditures of this branch of the office since December 15, 1888, the date of the Preliminary Report:

FINANCIAL STATEMENT.

Appropriation for Geological Survey of Texas, December 15, 1888, to December 31, 1889.

Balance of first appropriation		$11,016 29
Appropriation March 1, 1889, to February 28, 1890		35,000 00
Expended:		
Salaries	$21,796 28	
Field equipment	731 71	
Field expenses	6,234 48	
Instruments and apparatus	3,479 28	
Furniture and fittings	3,376 93	
Books and maps	403 38	
Laboratory supplies	1,309 86	
Printing	363 50	
Office supplies	161 87	
Incidentals	570 28	
Balance	7,588 72	
	$46,016 29	$46,016 29

Your obedient servant,

L. L. FOSTER,
Commissioner of Agriculture, Insurance, Statistics, and History.

GEOLOGICAL SURVEY OF TEXAS.

REPORT OF THE STATE GEOLOGIST

FOR

1889.

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LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY.
GEOLOGICAL SURVEY OF TEXAS,
AUSTIN, TEXAS, May 1, 1890.

Hon. L. L. Foster, Commissioner of Agriculture, Insurance, Statistics, and History:

DEAR SIR—I have the honor to transmit herewith the First Annual Report of the Geological and Mineralogical Survey of Texas.

The field work on which the Report is based covers the period from the organization of the Survey to January 1 of the present year, and it was found necessary during the preparation of the Report to supplement that work by trips in various directions, in order that the facts presented might be as complete as we desired to make them.

The Report is not intended to cover all that was done in this period, but only those parts which seem well established, and the publication of which will be of benefit to the State at large, and also to the workers on the Survey, leaving fuller details for future reports.

I desire also to express my thanks for your kind consideration and the assistance you have so willingly given me at all times during the progress of the work.

Yours, very truly,

E. T. DUMBLE,
State Geologist.

FIRST ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY OF TEXAS.

E. T. DUMBLE, STATE GEOLOGIST.

ORGANIZATION.

The preliminary organization of the Geological and Mineralogical Survey of Texas was effected, as is stated in the First Report of Progress,* by the appointment of W. H. Streeruwitz, W. F. Cummins, and R. A. F. Penrose, Jr., Geologists, and J. H. Herndon, Chemist, and the issuance of Circular No. 2, embodying the proposed basis of operations. This reads:

"The work will be particularly directed: 1st, to a search for ores, minerals, oils, coals, clays, and other materials possessing a commercial value, and the determination of the question, whenever possible, whether they exist in sufficient quantities, and under suitable conditions and surroundings, to make it reasonably certain that it will be profitable to work them; 2nd, to an investigation of the geologic formation and topography of the country, with a view to determining the probability of obtaining artesian water, and the feasibility of irrigating from such wells or from streams, shallow wells, or tanks where necessary; 3rd, to the determination of the adaptability of soils to certain crops, and how their fertility can be increased by the use of materials nearest at hand; and 4th, to the search for and development of useful articles as yet not fully known.

"The collection of fossils and study of geologic strata, though a necessary concomitant, will be made (as far as is consistent with obtaining a correct knowledge of their character and influences) subordinate and subsidiary to the economic features of the survey."

*Texas Geological and Mineralogical Survey. First Report of Progress. Austin, 1889. p. 7.

FIRST
ANNUAL REPORT

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E. T. DUMBLE, STATE GEOLOGIST.

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* [illegible] st Report of Progress [illegible]

The short time intervening between the preliminary organization of the Survey and the meeting of the Legislature, for which a report had to be prepared, made it necessary to spend the time in a very rapid reconnoissance of certain localities, in order to bring before that body the proofs that a geological survey was really a necessity. The proofs were so abundant that even within such a short period we were able, by using the services of several special assistants, to secure ample material for showing that there were mineral deposits in various parts of the State well worthy of such investigation as was contemplated by the law establishing the Survey.

Having demonstrated this, there followed the more serious business of perfecting the organization, mapping out the work to be done, and the selection and fitting out of the field parties. The working out of these details has been one to which the State Geologist has given his personal attention. They could not be arranged for *en masse*, but had to be taken up one by one, just as the necessity of the case called them forth.

The geologists named were each continued in the field with a definite line of work. Mr. Jermy, one of the special geologists of last year, was reappointed to the study of Geology and Botany of Gillespie County. Arrangements are perfected with the laboratory of the Agricultural and Mechanical College, at Bryan, similar to those with the University of Texas, and P. C. Tilson was appointed chemist for special work on the soils, clays, and fertilizers of the State. Mr. T. B. Comstock was engaged for special work in the Central Mineral District during the summer months, and at the close of his engagement he accepted an appointment as Geologist on the Survey.

Having received assurances from the United States Geological Survey of co-operation in the geologic features of our work, as well as in the topographic, I preferred a request to Maj. J. W. Powell, the Director, asking that Mr. Robt. T. Hill be detailed to carry on the study of the Cretaceous formation in Texas in connection with this Survey. This request was granted, and we have had the services of Mr. Hill, free of any cost to us, except for traveling expenses.

This completed the general organization, and the various changes which have been made will appear in their proper places.

SCOPE AND PLAN OF THE SURVEY.

The law creating this Survey designated it a "Geological and Mineralogical Survey," and its plain intent is that investigations and reports on the mineral and other natural resources of the State shall be its chief object.

Being in hearty accord with the tenor of the law, and believing the function of a State survey to be primarily that of economic geology, immediately upon my appointment as State Geologist I began the organization of the Survey upon this basis.

By economic geology I mean that side of geologic investigation which pertains to the search for, and description of, all materials occurring or being a part of the earth's structure, which can be made of use or profit to man. I do not by any means wish to imply that there is or can be, any antagonism between what is here termed economic geology and what is sometimes denominated scientific geology, for it is all one study, and there is not, nor can there be, any economic geology which has not its foundation upon a clear understanding of the science. I do mean, however, that the economic is that part of the science in which the people are most decidedly interested, and that the function of a State survey is to bring to light all possible facts regarding this branch of geology. This should include not only a statement of the how and where of the occurrence of useful materials, but also, when necessary and possible, a brief description of the manner in which they can be brought into use, simply and to the best advantage. Thus there are many of the rare minerals in the Central Mineral District, hitherto regarded as almost valueless, except as specimens for the cabinet of the mineralogist or in some museum, which, if found in sufficient quantity, are of value for certain purposes. It is the place of a State survey to discuss this, in order that the people may be apprised of their value. It is not enough to say that there is a limestone, and a clay near it, which might make good cement. Analyses should be made and the requisite quantities for the mixture shown; a statement made of the available fuel supply, and any other points bearing immediately upon the manufacture of the cement. So, too, the pottery clays must be studied, analyzed, described, and the particular kind of ware to which they are best adapted made known. In the deposits of ores and coal there are found many problems of a scientific nature, growing out of their geologic surroundings and bearing directly upon

their value, the solution of which must be obtained before satisfactory information can be given regarding their extent or the most economic method of working them. It is from a failure to appreciate this fact that so many mining enterprises have been unsuccessful. The laws that govern the formation and distribution of ores are as absolute as any others of Nature's enacting, and it is only through a thorough knowledge of them, and the interpretation of the observations according to their tenets, that mining can be successfully prosecuted. This is why it is necessary to have a correct idea of the geology of a district before making definite statements regarding its ores. The finding of a few inches of coal, or a few fragments of copper, have often cost a man thousands of dollars, because he reasoned that they must have come up from below, and that there must be more where they came from, when a knowledge of the geology of the region, and its teachings regarding the occurrence of such materials, would have prevented the expenditure of a cent.

The real connection of geology with agriculture is not at all appreciated as it should be. The fact that to the geologist every soil is as much of a rock as is a limestone, sandstone, or piece of gold ore, and therefore to be studied, is not generally taken into consideration, and consequently the idea prevails too often that geology can do nothing for the farmer. There can be no greater error. The search for minerals is only a part, and not by any means the largest part, of the geologist's work. Soils are but the results of the breaking down and decomposition of older rocks; and many of the rocks themselves are nothing but the altered and consolidated soils of long ago, whereon has flourished vegetation more abundant even than that of the present. To this vegetation we owe our beds of coal, and in some cases certain beds of minerals are traceable directly to its influence. More than all, it is the fundamental support of the present life of the earth, and therefore the critical study of its derivation, character and extent, its capabilities as productive soil, the materials for enriching it and making it more productive, are pre-eminently the study of the economic geologist. Nor do these general statements by any means include all the co-ordinate branches of economic geology, but sufficient has been said to show the breadth of the field it must occupy.

To accomplish these results an accurate knowledge of the general geology of the State is essential, and the most scientifie methods known and the results of all previous geologic research must be made use of,

and many new problems discussed and solved; but only such scientific investigations should be undertaken by a State survey as have a direct bearing upon the main point at issue. All others should be left to the specialist. Therefore the principle upon which I have endeavored to base this survey, and to impress upon each of my co-laborers, is, that while the work of the survey is economic geology, the only way to obtain accuracy of results is by application of the highest scientific methods.

In order that such work may be prosecuted in a manner to be of real benefit to the people of the State and at the same time with the requisite degree of rapidity, it is essential that two things be fully determined; first, the topography of the country must be known and mapped; and second, the general stratigraphic geology must be sufficiently well known to permit the geologist to devote himself to the economic features of his work. *Neither of these essential helps exist here.*

TOPOGRAPHY.

Accurate maps are of the greatest importance. They must show not only the correct geography of the country (although this is a great help), but must also include its varied topography. "Accurate topographic maps are essential to geologic study. Upon such maps the field geologist records his observations relating to the character of the rocky strata, the strikes, dips, etc., just as the land surveyor records his courses and distances upon a plat; and when the observations are completed he is able to take in the whole series of records at a glance, to generalize and to classify them, and to perceive the relations of the different veins and beds which it is desirable to distinguish, and thus in many cases to determine the relations of the strata far beyond the reach of actual observation, and sometimes to estimate the extent, thickness, and depth of the coal seams and other mineral deposits hundreds of feet below the surface. The topographic map is as essential to the field geologist as the plat to the surveyor, the plan and profile to the engineer, or the diagram to the architect."

At present there is no map of the State on which even the geography is shown correctly enough for our uses, and there is no State map at all giving any idea of the topography.

In our work, therefore, we have been obliged for the most part to use the county maps furnished by the Land Office, which, being compiled from the work of different surveyors, often show considerable dis-

crepancies when used in the field. Especially is this the case in the location and windings of streams. This is the natural consequence of the character of work from which they are compiled, which is intended to show only the position of streams with regard to survey lines. This could be obviated by meandering and mapping the streams, provided there was no conflict in survey lines, but, unhappily, such is not always the case.

Besides these and the work now being done by this Survey in the effort to prepare such maps as we need, based on accurate surveys, we have the topography of twenty to twenty-four thousand square miles (about one-twelfth of our entire area) in the center of the State, which has been done under the United States Geological Survey. While these maps are by far the best we have of this district, beautifully executed and very useful indeed, it is nevertheless a fact that they have proved so inaccurate in detail in many localities that we have been compelled to add a topographic corps to that of the geologists proper, wherever we have essayed to use them in anything like thorough work, such as that in the Central Mineral Region. These United States topographic maps cover only a certain belt of country, and they do not give us exactly the areas which are of most service to us. Thus the sheets take in *part* of the Central Mineral Region, *part* of the Central Coal Field, and *part* of the Eastern Cretaceous Belt; and they are now working eastward into a comparatively level country, in which, if anywhere, the geologist could manage to prosecute his studies without them, leaving those portions of the regions mentioned where they are most needed unfinished, and thereby increasing our work instead of helping us.

GEOLOGY.

All geologic work heretofore done in Texas has been of such a disconnected character that we are unable to formulate any general results from it, although many of the observations will be of great assistance in working out the local geology. The several expeditions made along the boundaries of the State and across it in various directions, were too hurried to give anything more than sketches of a few localities. Dr. Ferdinand Rœmer gave an excellent section of one district as he saw it, and for his opportunities a remarkably comprehensive view of the geology of the State, but this has subsequently been somewhat modified by other observers. Of the first State survey of Dr. Shumard we

have no definite detailed account, except in the Central Region, and in the later ones little attention was given to the subject. The State and its problems were too great to be compressed into the small amount of work which could be done under the appropriations.

All other work has been on detached areas, and for most part the results are summed up in short magazine articles.* Later, good work has been done by Mr. R. T. Hill, who has done much to give us a clear understanding of the Cretaceous, but even this is still very incomplete, and we may well say that the principal facts of our geologic history as a whole are even to-day unknown, except in so far as the work of the present survey has brought them to light.

PLAN OF OPERATIONS.

The plan adopted consists in giving the geologist in charge of the field party a definite line of work under general instructions, leaving the greater part of the details to be determined by himself, he being directly responsible to the State Geologist for the results. This works most admirably in practice, for while it furnishes the results as desired and planned for by the State Geologist, it allows the individuality of each geologist to be clearly seen through his report. Many of the minor details were settled by conference during the visits of the State Geologist to the different camps.

The present condition of the field parties, the amount of work they have accomplished, and the spirit in which it has been done, is proof of the satisfactoriness of the arrangements.

A knowledge of the general geology being a prime necessity in the carrying out of the objects of the Survey, the work of the present year was distributed in such a manner that while each field party had some distinct economic feature as a basis for the season's work, its relations and position were such as to necessitate a study of the details of the formation in which it occurred.

Mr. Penrose, in his report on the iron ores of Eastern Texas, necessarily gives the general geology of the Tertiary and later formations in which they occur, in order to show the manner of their deposition, their origin, character, and their relations to each other and to the formations containing them. The next older formation, the

*A detailed account of all work done previous to the organization of the present survey will be found in Bulletin No. 45 of the United States Geological Survey. "Present Condition of Knowledge of the Geology of Texas." R. T. Hill.

Cretaceous, is one to which the State owes much of its wealth, on account of the richness of the soils which had their origin in its rocks. Mr. Hill's work brings out its structure with reference to the artesian water and other economic features. So the problems of the coal, the gypsum, and the salt, which are now being investigated by Messrs. Cummins and Tarr, will bring out the stratigraphy of the Carboniferous period, while the geology of the older formations in their relation to their useful contents is shown in greater or less detail by Mr. Comstock in Central Texas, and Mr. Streeruwitz in the west.

Thus we have from these reports, in addition to the facts regarding economic geology, valuable as these are themselves, other information regarding the general geologic history of our State, sufficient at least for a present working basis, which will be increased by the observations of each succeeding season, and prove no less valuable in the assistance it will give in the further prosecution of the survey.

WORK OF THE FIRST YEAR.

TOPOGRAPHY.

TRANS-PECOS TEXAS.

The geography and topography of the Trans-Pecos region was almost entirely unknown. The location of the different mountains, and even the names by which they are designated, are differently laid down by the various cartographers. I made an effort to secure the assistance of the United States Geological Survey in this district, but being unsuccessful, I organized a topographic survey there with Mr. W. H. Streeruwitz in charge.

In order that we might secure the necessary degree of accuracy in the measurement of a base line I made application to Hon. T. C. Mendenhall, Superintendent of the United States Coast and Geodetic Survey, for the loan of a pair of four-metre base bars. The request was granted, and the bars were furnished, and the survey had the use of them without any expense beyond the freight.

The work that has been done is of as high a degree of accuracy as it is possible to obtain with the instruments at our command, and the maps now finished will be sufficient for the geologic work of next year in that district.

No trouble is anticipated in keeping the topographic work far enough ahead to prevent any further delays.

CENTRAL MINERAL DISTRICT.

In this district it was found necessary to add a topographic party to that of Mr. Comstock, to secure correct maps and furnish other requisite data for his use. Mr. Nagle and two assistants were, therefore, employed during the entire fall season in this most necessary work.

GEOLOGY.

TRANS-PECOS TEXAS.

Mr. Streeruwitz completed the preliminary reconnaissance of Presidio, Buchel, Foley, and Brewster counties, finding in the mountain ranges the same favorable conditions for mineral prospects as those decribed in the First Report of Progress.

In May he again took the field with instructions to begin a topographic survey of the Trans-Pecos District, and to devote the entire season to this work, only using such time for geologic investigation as could be given without hindering the progress of mapping.

Prof. H. H. Harrington, of the Agricultural and Mechanical College, was appointed to make an examination of the soils and water of the Rio Grande Valley, which he did without any cost to the Survey beyond his actual field expenses. The results are embodied in Bulletin No. 2.

I visited this district three times during the season, and made such examinations of the geology of the region as the short time at my disposal permitted.

NORTH TEXAS.

Mr. Cummins completed his preliminary survey over the northern portion of the coal field, and in March started for Lampasas for a similar investigation of the southern portion. Having completed this, I instructed him to proceed westward and take up the study of the Permian formation with its deposits of gypsum and salt. I joined his party in October, and together we made a preliminary section from Abilene north to Throckmorton County, and thence west to the Double Mountains, in Stonewall County. There being no reliable maps of the region, Mr. Drake was detailed to run a transit line and line of levels for the purpose of getting an exact section, and joined Mr. Cummins in November. This line and section was started from Albany, and runs

northwest to the Staked Plains, beyond Dockum's Ranch, and is to be carried from that point northeast to Wichita Falls.

Mr. R. S. Tarr was appointed in September to make a more thorough and detailed survey of the southern part of the Central Coal Field, the results of which appear in his paper accompanying this report.

EAST TEXAS.

Mr. Penrose spent the early part of the year in the detailed investigation of the iron ore localities of Cherokee County. Finding that the exact relations of the various deposits could not be made out in that region on account of the character of the topography and timber growth, he was instructed to make three river trips for the purpose of acquiring the facts requisite for this purpose. The first of these trips, on the Colorado River from Austin to La Grange, was made by Mr. Penrose and myself (accompanied by Mr. Hill as far as Bastrop); the second was made by Mr. Penrose, alone, down the Brazos River, from Waco to Hempstead. The third and longest was that which I made with Mr. Penrose down the Rio Grande, from Eagle Pass to Hidalgo or Edinburgh. On this trip we were accompanied by Mr. L. L. Foster from Eagle Pass to Laredo. These trips yielded us results of great value, the greater part of which appear in the report of Mr. Penrose.

Mr. Penrose left the Survey July 1, and Mr. G. E. Ladd was appointed to study and map the iron ore deposits of East Texas. After having worked over Upshur, Wood, Van Zandt, Marion, and Anderson counties, he resigned from the Survey. Mr. A. G. Taff was then appointed to continue the work, and took up the mapping of the Cass County deposits, which, however, he did not complete, having had to leave the field on account of sickness.

CENTRAL MINERAL DISTRICT.

Mr. T. B. Comstock was given the special work of the geology of this district, which was, as we supposed, fully covered by the topographic maps of the United States Geological Survey. Finding, however, that the details were not sufficiently accurate for the complications he found in the work, a topographic corps, under Mr. J. C. Nagle, was added. The work was much retarded on account of having to run so many lines, and at the end of his engagement, which was only for three months, Mr. Comstock was appointed geologist on the Survey and put in charge of the district. The results of his work are of great

interest, and such of them as are ready for publication appear herewith.

Mr. Jermy was appointed to examine the lower portion of this area, in Gillespie County. A resume of his observations will be given later.

CRETACEOUS AREA.

In February, Mr. R. T. Hill was given the study of this area north of the Colorado River, which he undertook, in connection with his work at the University, without any personal remuneration from the Survey. Mr. J. A. Taff was appointed to carry on the necessary field work under his direction. He has also had the services at different times of Messrs. McCulloch, Drake, and Stone. In July, Maj. J. W. Powell, Director of the United States Geological Survey, at my request, appointed Mr. Hill Assistant Geologist and detailed him to carry on the work already begun. Under this appointment he has also prepared for publication a check list of the invertebrate fossils of the Cretaceous System of Texas, which has been published as Bulletin No. 4, for the use of this Survey.

CHEMICAL LABORATORY.

Mr. J. H. Herndon, assisted by Messrs. R. B. Halley and M. M. Smith, performed all the analytical work, except soil analyses, which was done up to the first of June. At this time the two assistants resigned, and Mr. Herndon worked alone until August, when Mr. L. E. Magnenat was appointed. The arrangement by which the Survey was furnished with laboratory facilities by the University of Texas was terminated by that institution for want of room on October 1. I then made arrangements for laboratory work in the basement of the Capitol building, but two entire months were lost in getting together the necessary furniture, apparatus, and supplies, and there only remained the month of December for much-needed work for this report. So that it is only by reason of the delayed publication that results are given so fully as they are.

Mr. P. S. Tilson was appointed chemist at the laboratory of the Agricultural and Mechanical College, in January, and has been steadily engaged on the analyses of the various soils of the State during the entire year, with the exception of a few weeks spent with Mr. Comstock's party, in Llano county, for the purpose of collecting the soils of that district for study.

The work of the chemists appears in part in the reports of the dif-

ferent geologists. A more complete and detailed statement of this work will appear in the report of next year.

THE MUSEUM.

The museum cases supplied by the Capitol Furnishing Board were put in place in April, and as the specimens then on hand completely filled them, the unexpended balance of the first appropriation for the Survey was used to purchase additional cases for the preservation of the material collected by the field parties. These cases and their arrangement in the hall of the Museum are from designs most kindly furnished by Mr. G. Browne Goode, Assistant Secretary of the Smithsonian Institution, and are admirably adapted for the purposes intended. While they are well filled with specimens, the work of unpacking, labelling, and studying the various collections as they came in, has up to the present prevented anything like a systematic arrangement of the material shown. Mr. J. B. Walker has had charge of this work since April 1.

LIBRARY.

Books of reference are most necessary to the geologist, and there were very few in the State Library having any reference to the work. I have done what I could to remedy the deficiency by securing such works as I was able to obtain by correspondence and exchange or purchase, but the amount of money that I could use for this purpose was so small and the volume of necessary literature so great that we are still very much hindered in our work by reason of this deficiency.

OFFICE WORK.

The routine work of the office has been very considerable, and while it has required much time and close application, it is not of such a character as to be detailed, or even summed up in any but the most general terms. In it I have had the assistance of Mr. J. L. Jones during the entire year, and of Mr. C. C. McCulloch, Jr., when he was not in the field.

RESULTS.

A REVIEW OF TEXAS GEOLOGY AS DEVELOPED BY THE WORK OF THE SURVEY.

As a primary fact established by the work of this survey, it may be stated that Texas is a geological centre or focus. Situated as she is at the centre of the southern border of the United States, the converging lines of the geologic formations which mark the eastern ocean and gulf coast, as well as those of the central basin and western mountain system, all meet within her borders. Here it is that the true relations of each to the other may be best ascertained, and it will require the facts, that will only be brought to light by detailed study of these relations as they do exist here, to properly explain and interpret much that is now in doubt in the regions further north.

These various converging areas may be said to divide Texas into four districts.

The first of these, which is a continuation of those formations bordering the Gulf shores of the States east of us, comprises that portion of Texas lying between the Gulf coast and the foot of the Grand Prairie region. In no place does the altitude of this broad belt exceed 700 feet above the sea level. Beginning at the coast in level prairies, it gradually becomes undulating, and then hilly, until it meets the higher hills which form the scarp bounding it on the north and west.

From this boundary line to the foot of the Staked Plains is a second district which stretches away to the Rio Grande and Pecos of the south and west. This district may be subdivided into a plateau on the east and south called the Grand Prairie and an interior basin. This also rises gradually towards its western border, and, though containing many hills and mountains, nowhere is there an altitude of over 2500 feet. Within the encircling rocks of more recent deposition, there lies within this district, like an island in the sea, the older nucleus of the Llano or Central Mineral District, which can well claim close relationship with the oldest rocks which have been found upon our continent.

The Staked Plains, which form the third district, rise from 300 to 400 feet higher, and are a part of the great plains which stretch eastward from the foot of the Rocky Mountains. These plains, while in reality they rise rapidly towards the west, seem almost like a level floor,

cut here and there by canyons, formed by the encroaching action of the headwaters of the Colorado, Brazos, and Red rivers.

The fourth district comprises that portion of the country beyond the Pecos River, which is a part of the Rocky Mountains themselves, crossing the western border of the State, as they trend from New Mexico, and find their continuation in the rich mineral districts of the Mexican Republic. Here there are real mountains, which lift their peaks from 6000 to 8000 feet above the waters of the Gulf, often rising directly from the surrounding comparatively level plains, or flats of lake deposit, which enclose them on every side. These so mask the real relations existing between the ranges, and even between individual peaks of a range, as to render the accurate determination of their connection with each other a matter of considerable difficulty. Thus it is that we have within our borders most of the phases of American geology, and indeed some conditions which have not been hitherto observed on this continent, and which resemble more nearly those of Europe.

Not only is it true that we have here representatives of all these different formations, but their areal distribution is on a scale commensurate with Texan greatness. Comprising, as Texas does, one-twelfth of the area of the United States, some of her single formations cover a larger area than is found within the entire borders of some of the single States, and those by no means the smallest. Taking these facts into consideration, the amount of labor before us can be more readily understood, and the results here given be more nearly appreciated at their proper value.

Geologists divide the various strata or layers which go to make up the crust of the earth, as we know it, into four main groups. This division is based upon the character of the fossil remains which are found preserved in each separate group, and which show the progress of life in the history of our globe. From long continued observations of the positions and relations of the various beds, layers, or strata to one another, and the constancy of the occurrence of certain fossil forms of animal or vegetable life in each at a definite horizon, the order of succession has been made out. These general groups have in turn been subdivided. Each of these formations is usually accompanied by certain articles of economic importance, which are the results of the manner of their deposition, or of alterations which have taken place

TABLE OF

Progress Table showing the geologic formations found in Tex

System (Period).	Series (Epoch).	Division (Age).	
QUATERNARY.		*Coast Clays.*	
TERTIARY.		*Fayette (Blanco Canyon?).*	Sands, Clays, and
		Timber Belt, or Sabine River.	Sands, Clays, Gr
		Basal Clays.	Clays.
CRETACEOUS.	UPPER, OR BLACK PRAIRIE.	*Glauconitic.*	Glauconite Sands
		Ponderosa Marls.	Clays.
		Austin Chalk.	Chalk and Limes
		Eagle Ford Shales.	Clays.
		Lower Cross Timber Sands.	Sands.
	LOWER, OR COMANCHE.	*Washita.*	Limestones.
		Fredericksburg.	Limestones.
		Trinity.	Sands.
JURA-TRIAS.		*Dockum?*	Sandstone and C
PERMIAN.		*Double Mountain.*	Clays, Sandston
		Clear Fork.	Limestone, Clay
		Wichita.	Clays, Sands, an
CARBONIFEROUS.	COAL MEASURES.	*Coleman-Albany.*	Clays, Sands.
		Waldrip-Cisco.	Limestone, Clay
		Brownwood-Canyon.	Limestones.
		Milburn-Strawn.	Clays, Coal, Lin
		Richland-Gordon.	Sandstone.
	LOWER CARBONIFEROUS?	*Bend.*	Limestone and
DEVONIAN.		?	
UPPER SILURIAN?			
SILURIAN.	SAN SABA.	*Deep Creek.*	Dolomites and
		Hinton.	Dolomites, etc.
	LEON.	*Hoover.*	Burnet Marble.
		Wyo.	Brown Dolomi
		Beaver. *Bluff.*	Siliceous Magn
		Cavern.	Sandy Shaly D
CAMBRIAN.	KATEMCY.	*Potsdam Limestone.*	Limestone and
		Potsdam Flags.	Shales.
		Potsdam Sandstone.	White and red
	RILEY.		Chocolate Lim
			Calcareous Sa
			Sandy Shales.
	HICKORY.		Massive Sand
			Coarse Conglo
TEXAN.	PACKSADDLE.		Marbles and S
	LLANO.		Quartzites and
	MASON.		Sandy Shales
FERNANDAN.	CLICK.		Calcareous R
			Chloritic slate
			Carbonaceous
	IRON MOUNTAIN.		Ferruginous
			Quartzite.
	VALLEY SPRING.		Acidic Schist.
			Basic Schist.
BURNETAN.	BODEVILLE.		Mica and Chl
	LONG MOUNTAIN.		Hornblende a
	LONE GROVE.		Granite, Gnei

MATIONS.

ir probable correlations, as determined to January 1, 1890.

	Division.	Series.	System.	Group (Era).
		Champlain.	QUATERNARY.	
		Miocene.		CENOZOIC.
and Lignites.			TERTIARY.	
		Eocene		
	Fox Hill. *Pierre.* *Niobrara.* *Benton.* *Dakota.*	Upper Cretaceous.	CRETACEOUS.	
	Potomac.	Lower Cretaceous.		MESOZOIC.
e.			JURASSIC. TRIASSIC.	
Gypsum.			PERMIAN.	
al				
		Coal Measures.	CARBONIFEROUS.	
		Subcarboniferous.		
			DEVONIAN	
		Niagaran.	UPPER SILURIAN.	PALEOZOIC.
	Hudson. *Birdseye, etc.*	Trenton.		
es.	*Chazy.* *Middle Canadian.* *Lower Canadian.*	Canadian.	LOWER SILURIAN.	
nglomerate.				
		Potsdam.		
		Middle Cambrian.	CAMBRIAN.	
		Lower Cambrian.		
Eruptives.			ALGONKIAN?	EPARCHÆAN.
			ONTARIAN?	
				ARCHÆAN.
tit.			LAURENTIAN?	

in them. Those so far observed in Texas formations will be found enumerated in the general description.

A reference to the table on Plate III will give at a glance the general relation existing between each formation and those adjacent. From this table it will be seen that we have in Texas representatives of nearly every group and system known in the United States, and also the Lower Cretaceous and Lower Permian series, which are rarely represented elsewhere on this continent. The detail and full definition of the boundaries, character, and resources of each of these formations remains as the future work of the Survey.

The work of the past year has mainly been directed to the acquirement of a knowledge of the different formations occurring in the State, the character of materials composing them, their economic possibilities, and some idea of their extent, as a basis for our future work. The work was necessarily of the character of a reconnoissance, and there still remains much of the same kind of work to be done, but the main facts as here presented give us a good working knowledge of these conditions, and enable us to formulate our plans in such manner as will secure more rapid and satisfactory returns in the future.

In a general geologic description of a region it is customary to begin with its older rocks, as being not only the first in time of formation but in a measure the source from which were derived the greater part of the materials entering into the composition of those that succeed them. In reversing this method, as is done in the following pages, respect has been had merely to convenience of description by beginning at those formations the main features of which are best known to our general public, and therefore most readily explainable in a simple manner.

GULF COAST FORMATIONS.

The exposed portions of those formations which occupy the Coast District (which is, as has been stated, the continuation of that bordering the Gulf shore of the States east of us) comprise the Coastal Clays, the entire Gulf Tertiary Section, and part of the Cretaceous System, and these are arranged in belts, the general boundaries of which are approximately parallel to the present coast line. The normal dip or inclination of the strata of these formations is towards the southeast, and, while it is very gentle, it is greater than the average slope of the present surface in the same direction, and therefore the newest beds are

along the coast, and as we pass towards the interior we find the exposed areas of the outcroppings of the older strata of these formations succeeding each other in regular descending order.

All strata southeast of the oldest rocks of Llano County have a general dip southeast, while those northwest, excepting the strata of the Cretaceous, usually dip northwest.

QUATERNARY.

COAST CLAYS.

Immediately bordering the Gulf shore, and forming the underlying slope, on which its waves roll their sands and help to build the bars and islands that fringe the mainland of our State, and further inland rising into bluffs against whose feet the gently moving waters of its bays beat ceaselessly, we find a series of beds of clays, and sandy clays, blue, yellow, red, and often mottled, which frequently appear black upon the surface, from the combination of vegetable matter with the lime of the calcareous nodules which are found scattered through them. These clays are heavy, massive, containing small crystals of gypsum in places, and are so compact that bluffs of from fifteen to twenty feet in height are often found along the streams and bay shores, even in such a moist climate as that of Eastern Texas.

The various strata which form these beds dip so slightly to the southeast as to appear nearly horizontal, and form the basis of the level coast prairies, which stretch inland from the Gulf for distances varying from 50 to 100 miles, their broad expanses broken only by the timber fringing the streams which cross them, and the islands or motts of live oak, pin oak, and sweet gum scattered here and there. This gentle dip prevents their natural drainage to some extent, and for this reason they have not yet reached that state of agricultural development which the exceeding richness of their soil most certainly warrants.

The prairies rise gradually and gently from the Gulf, and the only elevations (except Damon's Mound, Brazoria county,) are small mounds of from ten to twenty feet in diameter, and not more than two or three feet in height, which are composed of soil differing in some degree from that immediately surrounding them, and covered by entirely different vegetation from that of the adjacent prairie.

Throughout the region where these clays prevail the dry weather of the summer causes them to crack open in extended seams of considerable depth, which are closed again by the swelling of the clay directly

after a heavy rainfall, causing what is generally known as "hog-wallow" prairie.

While the underlying beds of clay are seemingly identical for the entire Gulf coast, the overlying soil is somewhat different, being more sandy on the eastern and western borders, and more clayey between the Brazos and Nueces rivers. The great fertility of these soils is fully proved, not only by their analyses, but by the actual farming done on them. The fruit farms in the vicinity of Alvin, the "Sugar Bowl" of of the Brazos River (which is in part the weathering of these clays, and in part the river silt deposit), the cotton land of the coast prairie counties between the Brazos and the Nueces rivers, and the sugar belt of the Rio Grande all demonstrate the fact.

These clays vary considerably in quality, some containing an excess of iron or lime, while others are sufficiently pure for many industrial uses. From them are made all the building brick used in Southern Texas, and some kinds are so refractory as to be used as fire clays. At Harrisburg they are being manufactured into flower pots and charcoal furnaces, and a closer study of their composition and distribution will probably prove their perfect adaptability to other uses.

Throughout the whole of this region there is a reasonable certainty of securing a flow of artesian water by boring to a proper depth, and that a comparatively slight one. The rains which fall upon the sandy belt of country (Fayette Beds) which is exposed north of the Coast Clays, are partially absorbed by it and carried under them by its dip. Therefore, when the topographic features are favorable, artesian water will be found. It will, however, be sometimes more or less highly mineralized on account of the various soluble minerals contained in those beds, as is explained hereafter. The artesian wells of Houston, Galveston, Corpus Christi, and other places within the coast prairie country are from these beds, and vary from 150 to over 800 feet in depth.

TERTIARY.

FAYETTE BEDS.

The Coast Clays lie directly upon a great bed of sands, sandstones, and clays, more or less calcareous, which are here designated for convenience of definition and description "Fayette Beds," from the beautiful bluffs just south of La Grange, in Fayette County, where they are well displayed. They occupy the gently rolling country directly ad-

joining the area covered by the Coast Clays, under which the beds gently dip towards the Gulf.

This region, which is of varying width—in places not more than forty miles (perhaps considerably less), while in others it widens out to one hundred miles or more—stretches entirely across the State from the Sabine River to the Rio Grande, with its lower border from fifty to one hundred miles from the present coast line. In its eastern portion it carries a good growth of timber, interspersed here and there with prairies, but as we trace it to the southwest the forests grow continually thinner, until we find ourselves upon a rolling prairie, with timber only on the streams or in scattered islands, and consisting principally of post oak.

The soils of this district, like those of the coast clays, are highly productive, and their fertility is from the same source—the lime which they contain. They are mostly of a black clayey or sandy character, and the crops grown upon them compare favorably with those of any portion of the State, both in variety and amount.

From these facts, together with its favorable location and the amount of rainfall which visits the greater portion of it, this division bids fair, when its capabilities are more thoroughly understood, to rival even the famous black waxy soil of Central Texas.

These Fayette Beds include all the beds of clays and sands lying below the Coast Clays and the more recent limestone and pebble deposits, and above the uppermost fossiliferous stratum of the Marine-Tertiary.

Their upper portion consists of sands and sandstones, with seams and concretions of calcareous matter. The lower portion is composed of beds of clay and lignite.

The sandy strata are very variable in thickness and in consistency, although composed almost entirely of pure, coarse, siliceous sand, generally quite sharp, and containing a few red grains. In color they vary from gray to light buff and even white, and frequently contain lenticular beds of a very coarse sand. In places they are uncompacted, forming sand beds; in others, more or less indurated, forming sandstones, which vary in hardness from one that can be crumbled with the fingers to that of a quartzite proper. In these sands and sandstones are found large quantities of petrified wood, in the form of wood opal, often showing delicate shades of banding.

The underlying clays also differ greatly in structure and in color, varying from massive beds to thin laminations, and showing many dif-

ferent shades of color, from chocolate to very light greens and blues. The colors usually become lighter as we approach the top of the series. These clays are very hard, and weather to a pure white, giving rise to bluffs which are sometimes miscalled chalk bluffs on that account. Sulphur and gypsum are very abundant, as well as nodules and concretions of carbonate of lime. Even the chocolate clays often weather white upon the surface, and must be dug into before they will reveal their true character. This is due to certain chemical reactions which take place among the included minerals and vegetable matter, resulting in decomposing and leaching out the small amount of iron and carbonaceous matters contained in the surface of the clays. Lignite beds are found in connection with them, but there has not been time to examine them closely enough to reach any decision as to their probable value.

Many of the clays of this formation will prove of great value for pottery, fire brick, and similar uses. Some of them are free from iron and other objectionable ingredients, and burn to a pure clean white color; others, somewhat less pure, still vitrify beautifully on burning, and closely resemble the body of the common Chinese china. They are especially adapted to the manufacture of paving tile and brick, either alone or mixed with other clays. The sands furnish most excellent material for mortar and plaster, being sharp, light colored, and clean. The sandstones are of great value as building material. They are now being extensively quarried for use as rock material for the jetties at Galveston bar and the mouth of the Brazos. These beds of sandstone cross the Neches at Rockland, the Trinity at Trinity, the Colorado at La Grange, and are found at many other localities between and beyond these points. It is in them and the overlying sands that the water-bearing beds exist from which artesian water is obtained throughout the Gulf coast prairies.

Along the rivers of Central Texas these alternating beds of sands and clays so store and hold the water as to make their exposed edges the natural home of the most luxuriant fern growth, the exquisite beauties of which can nowhere be surpassed.

Overlying these beds are large deposits of gravel drift, which are used largely in the cities for paving purposes.

TIMBER BELT BEDS.

Proceeding toward the interior, we pass from the Fayette Beds to another series of strata which are tentatively called the Timber Belt Beds. The country underlaid by these beds is rolling and broken, and, in the east, heavily timbered. It rises above the Gulf from 200 to 600 feet, and some of the hill tops reach nearly 100 feet higher. All the hills of this district are, however, due simply to the erosive action of atmospheric influences, as nowhere is there evidence of any disturbance since the deposition of the beds, beyond that gradual continental rising which has lifted them so high above the sea whose bottom they once occupied. These high hills are capped by a stratum of iron ore or sandstone, the extreme hardness of which has resisted the erosive influence of the atmosphere, and thus preserved its underlying clays from being carried away. The outcrop of these beds occupies a belt of country 125 miles wide at its northeastern border, but narrowing to 40 miles north of the Colorado. They are composed of siliceous sand and greensand marls, together with white, brown, or black clays in smaller quantities. Lignite beds are of frequent occurrence, and vary from a few inches to twelve or fourteen feet in thickness. Petroleum, asphalt, and natural gas have also been found at places in considerable quantities.

The sands are usually much cross-bedded, and vary in color from gray to buff. In them are found small black specks of glauconite or greensand (which seems a common and persistent characteristic of these beds), and all degrees of combination may be observed, from a nearly pure siliceous sand, with only traces of glauconite, to a greensand marl. These marls occur in considerable quantities in the iron districts of Eastern Texas. Thin seams or beds of limestone are also found, and calcareous concretions or nodules, similar to those of the Coast Clays, are abundant throughout this whole series of beds. Sometimes the carbonate of lime, instead of being thus segregated, is disseminated throughout the sand beds, cementing them into a loose friable rock.

Masses of sandstone formed in this manner, and varying from a few inches to ten feet in diameter, are a highly characteristic feature. They are usually lenticular, although they are also found in other shapes, and while sometimes soft and friable, are often firm and hard. At times they weather in concentric layers, while at others the horizontal strati-

fication of the surrounding beds is seemingly repeated in them, and they gradually blend into the soft encirclihg sand. In places they appear as detached masses, at others form almost a solid stratum. This calcareous cement is occasionally replaced by a firm impalpable white clay, which when wet renders the beds highly plastic, but dries into a firm and solid mass. From the manner of their formation, the sand beds themselves lack that continuity and persistency which we find in the similar rocks of the older formations, and there is every evidence that they were deposited under very similar conditions to those which exist to-day upon the Gulf coast. Indeed, the entire series of Tertiary and Post-Tertiary strata may well be called littoral or shore deposits, showing in their variations changes from open sea shore to bays and lagoons, with alternations of tide and flood and standing water, of peat bog and dry land. Not only are these conditions shown by the character of the sediments themselves, but the extensive deposits of fossil shells found here and there in them, often separated by beds of lignite, furnish additional evidence that such were the conditions of their deposition. For this reason the graduations from sand to clays, and to sands again, both vertically and laterally, prevent the correlation of the beds at any distance, and render it difficult even when they are close to each other.

The clay beds which appear in the Timber Belt differ greatly in purity and color. Some are pure white, from which they are found in all colors, to brown and even black when the quantity of lignitic matter they contain is sufficiently great. They rarely appear massive, as in the upper beds, but are more usually thinly laminated, and often contain lenticular masses of sand scattered through them with considerable regularity of deposition.

The lignite is not in continuous beds, as is the case with the coal of the Carboniferous Period, but in lenticular beds of greater or less extent. It varies from a lignitic clay to a quality closely approaching a bituminous coal. In places it carries little or no sulphur, in others the amount of pyrites contained in it entirely unfits it for any use. The quantity of good lignite, however, is very great, although little effort has as yet been made to use it.

Iron is found in three forms throughout the Timber Belt Beds—combined with sulphur, in the form of pyrites, it is found in larger or smaller quantities in all parts of the beds, and thus has had its share in producing the workable iron ores of Eastern Texas, as will be stated later. Carbonate of iron, or clay-iron stone, occurs in masses under similar

conditions to those described under the concretionary sandstones, and the limonite or iron ore proper is found, as has already been mentioned, forming the capping of the higher hills of many of the eastern counties.

The mottled appearance of certain clays spoken of under the Coast Clays is also observable in the clays of this division.

The soils of the Timber Belt Beds differ with the underlying beds. In the lowlands the soils are red clay, red sand, or mulatto, just as they are underlaid by sands or clays respectively. The red color is due to the amount of ferruginous matter they contain from the decomposition of the glauconitic grains and pyrites, while the mulatto soil has its source in the decomposition of the beds of greensand marls. These marls, in addition to the glauconite they contain, which is itself a fertilizer of great value, are frequently filled with fossil shells, the composition of which increases their fertility to a considerable degree. For this reason these soils are frequently quite as productive as those of the river bottoms, whose supply of lime is acquired from the sediment deposited by the overflows of the rivers, which come to them through the great district of Cretaceous rocks lying north and west, and have in suspension considerable quantities of carbonate of lime taken up in the journey toward the sea. Upon the upland we find a gray sandy soil, grading downward into a red subsoil which is especially adapted to the growth of fruit.

Upon the Rio Grande these beds seem to rest directly upon the upper beds of the Cretaceous, without the interposition of those lower beds of the Tertiary which are present on the northern border, and which will be described under the head of "Basal Clays." The Timber Belt Beds here show the same character of formation as is exhibited in the east, and frequent beds of a large oyster, sometimes as much as twenty feet in thickness, are found interstratified from the top to the bottom of them. In general composition the various strata correspond very closely to those already described, but owing to the indurating effects of the dryer and hotter climate, there are certain remarkable differences in present appearance. Thus the table land appears in the west, as such, cut here and there by deep arroyas or incipient canyons, while in the east only the remnants of it remain as the iron capped hills. This gives to the western area a rugged appearance, which is heightened by the almost total absence of timber, so plentiful on the eastern border.

This area, so rich in soil and timber, is no less remarkable for the value of its mineral contents, among which we may mention the iron ores, lignite, petroleum, fire-clay, pottery-clay, glass-sand, and green-sand marls. The iron ores are not confined to this division, and therefore will be discussed later.

Lignite.—As has already been stated, the beds of lignite are numerous and the quantity is beyond question fully adequate to all demands that may be made upon it. The real value of this material as fuel is not at all appreciated. Lignite, up to the present time, has been regarded as of very little value. Two causes have been instrumental in creating this impression: first, the quality it possesses of rapidly slacking and crumbling when exposed to the air, and second (and perhaps this is the principal cause), all who have attempted to use it have done so without first studying its character and the best methods of burning it, and they have in most cases endeavored to use it under the same conditions which apply to a bituminous coal containing little water. While lignite may not differ materially from bituminous coal in weight, its physical properties are entirely different. This is due not only to the amount of water contained in the lignite, amounting to from ten to twenty per cent of its weight, but also to the fact that it is the product of a different period of geologic time and that its original vegetable growth was of somewhat different character from that from which bituminous coals are formed, and it may be that the method of formation differed in some way in the two. Therefore, in any intelligent effort to make it available for fuel, these considerations must be taken into account, and proper allowances made for them. In Europe, where fuel is scarcer than here, lignites of much poorer quality than our average deposits are successfully used, not only as fuel for domestic purposes but also for smelting.

The amount of sulphur contained in these lignites is very variable, as is indeed the quality of the lignite itself. In most places we have a good, clean lignite, almost if not entirely free from sulphur, but at other places masses of sulphuret of iron are mingled through a carbonaceous mass. The different methods of rendering it a truly serviceable and inexpensive fuel have been stated several times. The better grades can be advantageously used near the mines for steam making and household purposes, if properly constructed fire-boxes are used. By crushing and mixing with asphaltum or coal tar pitch at 212 degrees Fahr., much of the contained moisture will be driven off, and

on compression by suitable machinery a firm and durable briquette will be produced, perfectly adapted for all uses as fuel, clean, fully as desirable as ordinary coal, and at a lower cost. Instead of asphaltum, other cementing materials, such as starch, or even clay, are sometimes used, but the product is not usually as good. It is altogether probable that lignite could be used very profitably in the manufacture of water-gas, and thereby furnish the very cheapest of fuels for manufacturing purposes.

Laredo Coal.—While the Laredo Coal Seam belongs to the same series of beds as the lignites of the other parts of the State, local conditions have resulted in the formation of a fuel of much greater value than they. The seam outcrops at San Tomas, north of Laredo, and the San Tomas mine is connected with the city by a railroad. The mine opening is in the bank of the Rio Grande, about forty-seven feet above the river. The seam is from 30 to 36 inches in thickness, with a clay parting from 1 to 6 inches thick, which is usually about 12 inches from the top. The roof is of a tough black clay. The coal is massive, black, glossy, with conchoidal fracture, and in some places has a thin stratification similar to bituminous coal. It also resembles Albertite in some measure, though somewhat less glossy. Numerous other outcrops of the same coal are known in the surrounding hills. The coal is being extensively used as a fuel for all purposes and proves very satisfactory. We have no record of its having been successfully coked.

Gas.—In several places occupied by the outcroppings of the Tertiary strata borings have proven the presence of natural gas in considerable quantities. It is also known through natural openings in the eastern part of the State, and well deserves a special investigation.

Petroleum has been found in numerous localities in the area covered by the Timber Belt beds. It is, however, to be classed as a lubricant rather than an illuminating oil, and resembles the heavy West Virginia oils. The deposits, from the very nature of their origin, while very widespread, can not be of more than local extent; but at places, such as have been prospected already in Nacogdoches and San Augustine counties, these deposits, in spite of this local character, may prove of very considerable value. This is rendered very probable from the fact that they lie near the surface, and on that account the expense of boring wells is very little. In places this petroleum is hardened, by the evaporation of its more volatile parts, into asphaltum, more or less mixed with sand or calcareous matter, and such deposits

are found of an extent sufficiently great to make them of value to the neighboring towns for paving purposes at least. This is the case in the vicinity of Palestine, where the deposit is ample to supply this most valuable paving material for several of the surrounding towns.

The *fire-clays* and *pottery-clays* of this series of beds are among its most valuable deposits, rivaling, if they do not exceed, the value of the deposits of iron. Their high grade has been proved both by chemical analysis and by their manufacture (on a very small scale, as yet, however) into fire-brick, tile, and pottery. When they shall have been systematically studied, their different qualities and localities accurately determined, they must necessarily attract the attention they so surely deserve, and prove the basis of important industries.

Among the *sand beds* of this area are some deposits of pure white sand. In a few places this is mixed with a very pure kaolin, from which, however, it can easily be separated by washing. These sands are perfectly adapted to the manufacture of glass, and if the alkali deposits of West Texas (consisting in places of almost pure sulphate of soda) prove sufficiently abundant for use with them, we have the essential constituents of glass, and if we add to this the advantage of the cheap fuel of water gas, which we have every reason to believe can be produced from the lignite, we have every inducement for the erection of glass works on an extensive scale.

Greensand Marls.—The qualities of these valuable fertilizers have been mentioned in connection with the soils resulting from their decomposition. Too much can not be said in regard to their great value. The State of New Jersey to-day owes her agricultural possibilities to the existence and use of similar deposits within her borders. Without them their soils would often be practically useless. The potash, phosphoric acid, and iron contained in them are all valuable as plant foods. The decomposition of the material is generally very gradual, and therefore these elements are added to the soil, a little at a time, and for this reason it is a durable fertilizer. If it were necessary to secure more rapid results the decomposition of the material could be hastened by roasting it with access of air before applying it to the soil.* This fertilizer is especially valuable for fruit trees.

* Experiments on average greensand in the laboratory gave an increase of four hundred per cent of soluble potash after roasting.

THE BASAL CLAYS.

Between the Timber Belt beds and the underlying Cretaceous strata there are great beds of stratified clays with little sand, which are called the Basal or Wills Point clays. The country underlaid by them is the extreme eastern extension of the Central Texas prairies, interspersed with belts and groves of post oak, black jack, and hickory, and does not exceed ten miles in width, in places, though it extends from Red River to beyond the Colorado.

The clays are of various colors, stiff, laminated, with some interbedded seams of sands, and contain concretions of grey, non-fossiliferous limestone, and frequently fine crystals of gypsum. They are especially characterized by small segregations or concretions of calcareous matter of cauliflower-like form.

The soils vary from clay to clay loams, and as they contain much lime they are dark colored. The subsoils are yellow or grey clays with a little sand. The soils are very rich and produce as well as many of the soils of the black prairies, from the erosion of whose materials they were originally derived. These are the lowest beds of the Tertiary formation in Texas as far as has been determined, and seem to be entirely lacking on the Rio Grande. In their northeastern portion they contain deposits of iron ore which are of considerable value and which will be spoken of under that heading.

Iron Ores of the Tertiary.—The workable ores of the iron region of Eastern Texas, the value of which can hardly be overestimated, occur in the areas covered by the Basal clays and Timber Belt beds, and are either limonites or clay ironstones, the former being by far the most important. Limonite is a compound of iron and ogygen combined with a certain percentage of water. When perfectly pure it contains:

Water	14.40
Iron	59 92
Oxygen	25.68
	100.00

It is usually associated with clay or sand, and often contains small amounts of such impurities as phosphorus and sulphur. It is not often, however, that these impurities are present in the ore of this region in such quantities as to seriously interfere with the working of the ore. The clay ironstone or carbonate of iron, which has been reported as

existing in places in this district, has not yet been studied. This description is therefore confined to the different limonite ores. These limonites are of three forms:

Brown laminated ores.

Nodular or geode ores.

Conglomerate ores.

The first of these is the usual ore of the iron district south of the Sabine River, while the other two are principally found north of that stream. The origin of these different varieties of ore is reasonably well established by the investigations of the Survey. The beds of laminated ore are the results of the decomposition in place of iron pyrites, greensand marls, and the carbonate of lime of the included shells, the chemical action producing peroxide of iron, gypsum, and carbonic acid. The nodular or geode ores are probably derived from the older clay ironstones, while the conglomerate ores are but the results of the partial breaking up and re-cementing of other ores.

The laminated ores occur as beds of varying thickness, probably averaging about two feet at the tops of the hills, which are the remains of the ancient table lands of Eastern Texas, and are overlaid by sands of variable thickness, or in many cases by sandstone instead. This distribution is not entirely uniform, as they are present in some hills and absent from others, according to the existence or non-existence of conditions favorable to their formation. They are, however, abundant and rich, and are found in all gradations, from massive to coarsely laminated structure. In color they are rich brown, often black, and are found in many places throughout the counties lying below the Sabine River, at least as far south as Sabine County, and west to and beyond the Trinity River, but their extension west of that stream has not yet been traced. From our present knowledge of their composition, we can say that there are very few places where the ores are found in sufficient quantity for iron making (other conditions being favorable) at which the quality of ore is not good enough to warrant the erection of iron works.

The nodular or geode ores, although very similar to the laminated ores in their composition, differ widely from them in their mode of occurrence. They appear principally in the counties north of the Sabine River, in the shape of nodules or geodes, and of various forms of honeycombed, stalactitic, botryoidal, or mammillary structure. They vary in color from yellow to red, and sometimes a glossy black. These nodules or geodes occur in deposits of variable extent, at times as de-

tached masses scattered over the surface, at others in beds cemented with ferruginous material. These beds occupy the tops of the hills under similar conditions to the laminated ores, and the scattered deposits found are doubtless the result of the complete demolition of the hills which they formerly crested. The beds vary in thickness from one to ten feet, the thicker ones often being embedded with thin seams of sand. The geodes, when broken, often show a coating of red ochre.

The beds of conglomerate ores consist of brown ferruginous pebbles, sometimes two inches in diameter, cemented in a sandy matrix. They are generally local deposits, and sometimes reach a thickness of twenty feet. They are usually found along the banks and bluffs, and even in the beds of many of the streams, through the entire iron area of East Texas. They are not as rich as the other two grades of iron ore mentioned, but can be concentrated by crushing and washing.

The quality of the laminated and geode ores, and their adaptability for the manufacture of the better grades of iron, has been fully brought out by the work of the several small furnaces erected on them. They are now attracting the attention of capitalists, and new furnaces are just completed and in process of erection.

The details of the distribution, extent, and quality of these ores are now under investigation by the Survey. The boundaries of the different deposits have been accurately traced in five or six counties, and average specimens of the ore collected from each locality for analysis. As soon as this work can be completed over the entire district, a general map will be prepared, showing, in detail, the information thus acquired, and a full report made on the results of the analyses of the specimens collected.

CRETACEOUS SYSTEM.

These beds just described—the Basal Clays, Timber Belt, and Fayette Beds—taken together form the Texas Gulf section of the Tertiary System as it is known to geologists. As we pass on into the interior of the State, we find the outcropping edges of an entirely different series of strata underlying it, which we know as the Cretaceous (or Chalky) System. The general dip of the strata of this system is, like that of the Tertiary, to the southeast, and the boundaries of the areas occupied by the outcroppings of its various subdivisions have, like those of that system, a general parallelism to the present coast line of the State. The rocks of this system are divided into two series, the Upper or

Black Prairie and the Lower or Comanche. While the difference in the rocks of the two series is very marked, both are especially characterized by the amount of limestone and chalky material contained in them. These limy materials are found mixed with larger or smaller quantities of sand or clay.

Chalk is essentially a deposit formed in deep seas, and usually contains remains of minute forms of animal life which existed in the water. These deposits may retain their original character or be hardened by various agencies into limestones. Limestones are also formed of calcareous material worn away from the exposed land surface of other limestones through atmospheric influences, and carried out by various rivers until, on reaching less rapid water, they are gradually deposited, mixed with more or less sand or clay as they are nearer to or farther from the shore; at other times they owe their origin to the great shell beds, which remain to tell us of the former inhabitants of the seas. Thus we may judge from the character of the limestones the way in which they were formed.

These two series of Cretaceous rocks differ from those of the Tertiary in the manner of their formation and in their composition. The Tertiary strata were deposited somewhat after the manner of the beds now making along our seacoast, and the present manner is in reality a direct continuation of that older one, while the Cretaceous deposits, with their alternations of sands to clays and limestones and back to clays and sands again, as well as by the character of their fossils, show us clearly that the lower series represents a series in which the sea gradually grew deeper and deeper, and then again became shallower and shallower, until an emergence took place and there was dry land for ages. This was followed by a second period like the first, and the sandy beds, which were the last deposit previous to its final emergence before the beginning of the Tertiary period, became the shore line against and upon which the waters of the shallow seas, bays, and lagoons deposited the sediments which form the beds of that system.

UPPER CRETACEOUS SERIES.

The Upper, which is called the Black Prairie Series, from the Great Black Waxy Prairie, which is the representative of its most prominent member, is composed of the Glauconitic Beds (sands), the Ponderosa Marls (clays), the Austin Chalk (chalk and limestone), the Eagle Ford Clays, and the Lower Cross Timber Sands.

GLAUCONITIC BEDS.

Directly below the black clays on the northeast, and what is supposed to be the continuation of the Sabine River Beds on the southwest, there is a deposit of sands with clay, and a considerable amount of glauconite or greensand. The fossil shells found in it, in great numbers, are identical in species with many of those found in the greensand marls of New Jersey, and prove its close relationship to those in time or conditions of deposition. The admixture of sand and greensand with the clays of this belt, which is narrow in Northeast Texas (and of entirely unknown extent in the southwest), makes its resulting soil less sticky, and therefore more easily worked than the Main Black Prairie, which it so closely resembles in color and fertility. It must therefore be of necessity a most excellent fruit region.

THE PONDEROSA MARLS.

This great body of clay, which is the immediate source of that fertile soil so well known as the Black Wáxy Prairie, has a thickness of some twelve hundred feet. These clays lie directly below the sandy strata of the Glauconite Beds on the east, and rest on the gently sloping beds of the Austin Chalk, the outcrop of which marks their western boundary, giving us an area thousands of square miles in extent, which is one of the grandest agricultural countries of which we have any knowledge. They are originally of a light blue color, due to the iron they contain being combined with its minimum amount of oxygen, and seem to be very massive, but the action of atmospheric agencies brings out their laminated structure and gradually alters their color to yellow, by the combination of the iron with more oxygen, forming the peroxide (which is equivalent to iron rust); and finally, when the iron and limy material are acted upon by vegetation, it gives it the deep black color so characteristic of the soil.

The principal fossil found in these clays is a very heavy oyster, from which the clays receive their name. Toward the top, as the Glauconite Beds are neared, the clays become more fossiliferous, and many shells resembling those of the overyling beds are found. The great value of the Ponderosa Clay is in its superior soil, the elements of which are due to the material derived from the wearing away of portions of some of the older formations to the north and west, and their redeposition in their present localities. These consist of clays, lime,

and gypsum, and thus the beds contain within themselves the requisite elements for constantly renewing their fertility.

THE AUSTIN CHALK.

The Austin Chalk, which underlies the Ponderosa Marls, marks the middle portion of the Upper Cretaceous Series, during which its persistent chalky strata were deposited. While the area of its present exposure in Texas is only a comparatively narrow band, stretching from Red River to the Rio Grande, it was doubtless originally of great extent, and it carries on it to-day suoh cities as Dallas, Waco, Austin, and San Antonio. The rock is a comparatively pure white to bluish-white chalk of various degrees of induration and containing numerous *foraminifera* and casts of fossils.

The purity of much of the rock of this formation adapts it particularly for the manufacture of lime, great quantities of which are now produced from it, and also for the manufacture of Portland cement by combination with the clays adjacent to it. It may in time be used, where necessary, on lands deficient in lime, unless the greensand marls which are nearer to them are found to contain a sufficient quantity of that element in addition to its other ingredients of value. These rocks are also suitable in many instances for building material.

THE EAGLE FORD SHALES.

The Eagle Ford Shales which form the Minor Black Prairie west of the Austin Chalk are somewhat similar to the Ponderosa Marls, but are dark blue and shaly in the middle of the deposit, becoming more calcareous towards the top, and contain many large septaria and well-preserved fossils. Like the Ponderosa Marls, too, its principal economic value is its soil. The area of this deposit, as exposed in Texas, is comparatively small, but it is nevertheless a region of grand possibilities in agricultural and horticultural development. In Trans-Pecos Texas the Eagle Ford Shales with characteristic fossils are found in the northern part of the Eagle Mountains. A short distance north of the large springs they may be seen in a small detached area lying above strata of the Upper Carboniferous, from which they are separated only by a seam of intrusive porphyry, without any of the older Cretaceous rocks appearing. To the west of this, and beyond the small creek on which the Eagle coal mine is situated, there is a much larger deposit of the shales, cut in places by dikes containing pitch-

stone, etc. Through the center of the thick shales rises an immense chimney of dark red porphyry. *Inocerami* and *Ammonites* of distinctively characteristic forms were found here.

LOWER CROSS TIMBER SAND.

To the west and immediately below these clays as they occur east of the Brazos River, is found a series of sandy materials, whose areal extent is coincident with the timbers from which they receive their name. Sometimes they are ferruginated and also contain small deposits of lignite and particles of iron ore. The sands are frequently cross-bedded, and their whole formation tells of the littoral or near-shore conditions, which mark the beginning of the Upper Cretaceous subsidence. The soils, although sandy, sustain a rich timber growth, and are most suitable for the growing of fruit trees.

The Lower Cross Timbers or Dakota sandstones are represented in the foothills of the Diabolo Mountains, about four miles north of Eagle Flat, by a series of sandstone hills from two to four hundred feet in height, the stone of which is composed of rather coarse, sharp sands, white or yellow in color and weathering brown through oxidation of its iron. It carries a few pebbles in places, has some few seams of calcareous sandstone, and shows slight cross-bedding. This sandstone rests directly upon limestones containing fossils characteristic of the Washita Beds, but no fossils were found in the sands themselves. It was assigned to this position from its stratigraphic relations only.

In the Upper Cretaceous Series we have, outside the great fertility of its soils and its structural materials, which have already been mentioned, and the coal found in the neighborhood of Eagle Pass, which is described below, very little which at present can be described as being of economic value. Indications of petroleum and gas are found in places, but there is not sufficient data now in hand to make positive statements regarding them. The possible use of its chalks and marls as fertilizers on other lands of the State has also been referred to, and there only remains one resource, which is nevertheless one of the greatest importance, that is, artesian water. Throughout this whole area of the Upper Cretaceous as mapped herein there exists not only the possibility of securing artesian water at reasonable depths, but in the greater number of localities the certainty of doing so. The places at which it can not be gotten, owing to adverse topographic conditions or

interference in the water-bearing beds, are few in number. With the advantages of climate, rainfall, soil, health, and the boon of unfailing artesian water, this region is indeed a favored one.

EAGLE PASS COAL.—While the Cretaceous was for the greater part a period of marine conditions, there were periods which favored the formation of coal in larger or smaller quantities. Beginning even in the Trinity sands (to be described beyond), we find numerous traces of lignite, sometimes in considerable quantities. Higher in the series small seams of coal, sometimes approaching a bituminous character, are found, but are never more than a few inches in thickness and of very limited extent. The only exception now known occurs on the Rio Grande in the vicinity of Eagle Pass. Here there is a local deposit of considerable value. The fact of its existence and value is most interesting. It is the heaviest bed of coal that has yet been discovered in the State, averaging, according to our measurement, about five feet in thickness. It is a good fuel for household and steam purposes, but we have not yet been able to obtain any definite information in regard to its coking qualities under proper treatment. It is reported as forming a coke in a gas retort, but this is not a good criterion from which to judge of its merits or demerits, and the matter can not be regarded as finally settled until it has been given a fair test in properly constructed coke ovens. The great demand for coke for metallurgical purposes in Western Texas should be incentive enough to the owners of the mines to have these tests made.

Concerning the age of this bed many opinions have been expressed. It has been variously referred to the Carboniferous, Permian, Triassic, and Cretaceous, by different writers. Paleontologic evidence seems to prove that this bed is geologically lower than those known as "Laramie," to which Dr. White* decided the Sabinas, Mexico, coal belonged, and that it is clearly Upper Cretaceous; but it will require closer stratigraphic and paleontologic work than has yet been devoted to it to determine its exact horizon.

This coal bed dips to the southeast, as do the enclosing strata of this formation, and it will probably be found by boring at other places around Eagle Pass.

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*American Journal of Science, January, 1887, No. XXXIII, pp. 19, 20.

THE COMANCHE SERIES.

The Lower Division of the great Cretaceous System, called the Comanche Series, is, like the Upper, principally a prairie country, and is designated the Grand Prairie. Its eastern and southern boundary, as it now appears above the surface, is the last that shows any marked parallelism with the Gulf coast, and may mark approximately the ancient shore line of the sea in which the deposits already described were laid down. It is also the last of the upper formations in which we find the dip to the southeast prevailing. From Austin to the Rio Grande this boundary is marked by the range of hills (Balcones) which rise from one to two hundred feet above the undulating country at their feet. Between the Brazos and Red River the line is the western edge of the Lower Cross Timbers already described. The rocks of this series once covered the greater part of the area north and west of this line, and even now it is of wide extent, although we have only what is left after ages of erosion. This series consists of the Trinity sands, the Fredericksburg limestones and chalks, the Washita limestones, chalky in the east but more sandy towards the west, and the overlying clays. All of these divisions are represented in regular descending order, but to the west erosion has removed the softer upper strata in many places, leaving the hard limestone which is the highest stratum of the Fredericksburg division as the capping stone of the table lands, plateaus, and buttes, which owe their present existence to this protecting mantle. The topography of the Grand Prairie Region is highly characteristic. In places it stretches away in extended plateaus, which are comparatively level and generally treeless, cut by a few streams, whose valleys are often bounded by steep cliffs. At others long tongues or even buttes are all that are now left to mark the decay which it has undergone.

THE WASHITA DIVISION.

The Washita, which is the upper division of the Comanche Series, and therefore directly underlies the lowest beds of the Black Prairie Series, is composed in its upper part of alternations of clays and impure limestones, the fossils of which show clearly its littoral character. This part is called the Denison Beds. Below these come other clays, which, like the Ponderosa Marls, yield a rich black soil, and also like them are named from a fossil oyster—the Arietina (little ram's horn) clays. The areal extent of these Arietina clays is not great in Central

Texas, and they are only known by a few scattered fossils in the Trans-Pecos region.

The lower part of the division is composed of limestones. In the eastern part these limestones are chalky and show by their fossil remains a condition of deep and gradually shallowing water during their formation. They are of such character as to furnish excellent building material. In the Trans-Pecos region the upper limestone, known distinctively as the Washita limestone, has a far greater development than the thickness of the entire division, as it is known in the area north of the Colorado. In the range of hills between Sierra Blanca junction and the river it can not be less than one thousand feet in thickness. The limestones at this locality do not appear to have been affected by the porphyritic intrusions to such an extent as some of the underlying and overlying beds—probably on account of the more massive character of the strata of which they are composed. While they vary somewhat in color on the inside, they weather to a uniform greyish-blue, and to a casual observer present nothing different from the limestone of the underlying Cretaceous and Carboniferous. A careful examination, however. reveals a difference in the manner of weathering, which, while hard to describe, is nevertheless plainly apparent after a few observations on the different strata in the field. The limestones contain some sand and also more or less iron. When freshly broken they are often of a purplish color with numerous yellow clayey or ochreous spots scattered through them. There are also numerous bands of conglomerate or breccia interstratified among them. The distribution of these limestones is wide. They have been observed in the hills southwest of Finlay; in small detached areas in the Sierra Blanca group and Quitman Mountains (resting here directly upon the granites and porphyries); in the hills around Sierra Blanca Junction; and eastward from that point they form the Devil's Ridge, and occur well developed in the Eagle Mountains, on the west of the entrance to the spring. North of Eagle Flat they form two small buttes in the flat, and are seen again underlying the Lower Cross Timber sands to the north.

The fossils of these beds are very numerous and some of them exceedingly well preserved.

THE FREDERICKSBURG DIVISION.

This middle division of the Grand Prairie Series consists of chalky limestones underlaid by beds of limestones containing more or less

magnesia and frequently some clay, which become much more sandy and thin-bedded toward the bottom.

Below the lower beds of limestone of the Washita Division belongs the most persistent and highly characteristic bed of the Lower Cretaceous Period, which is known as the Caprina Limestone. Formed originally at the bottom of the deepest sea of Cretaceous times as a soft chalky mass, with beds of flints, and enclosing remains of animal life of most peculiar forms, it has gradually risen, portions of it becoming harder and harder, until, after untold ages of exposure, they now form the capstones whose protection has preserved much of the softer material which underlies them. To these hardened layers is due, in a large measure, the present extent of the Grand Prairie. The strata are not all hardened to this extent, however, and many of them are even yet almost true chalk. In Trans-Pecos Texas also, this limestone is one of the resisting agencies which have had much to do in shaping the topography of the country. Here it frequently forms the entire surface and slope of hills, as in the various ranges of the Sierra Blanca Region. It is readily distinguishable in most places by the peculiar manner of its weathering, which, while of very similar character to that of the other limestones, still has an individuality of its own, in the ferruginated or calcitic impressions or casts of its distinctive fossils, the *Caprina crassifibra*, Rœmer. Other fossils abound also, but the shell named seems to be by far the most abundant. Strata of this age were observed around Sierra Blanca Junction, where they are tilted and even cut by porphyritic intrusions. These limestones, in the more eastern part of the State, on account of their purity, are, like those of the Austin Chalk, especially adapted to the manufacture of lime, and are now extensively used for that purpose.

Between the Caprina Limestones and the Basal Trinity Sands we find everywhere present the chalky limestone belonging to the Comanche Peak Beds, filled with many beautiful fossils, and underlaid by the lower or alternating beds of sands and limestones, more or less magnesian. In these lower beds occur some interesting minerals, which are the result of chemical action which has taken place since the deposition of the rock. These include *Epsom salts*, *Celestite*, and *Anhydrite*.

TRINITY SANDS.

The lowest beds of the great Cretaceous system are composed of sands and pebbles derived from the ancient shore line of the earliest Cretace-

ous sea. Towards the top of the beds the deposits become finer, and where mixed with sufficient carbonate of lime to cement them, become packsands. These sands form the soil on which the eastern portion of the Upper Cross Timbers grow, and their line of outcrop forms the western border of the eastern Cretaceous area. While the Trinity sands do not furnish soils of great fertility, we are nevertheless indebted to them for the great artesian water area which they have created and of which they must always remain the source of supply. For this reason their value is far greater than it could be as mere farming land.

One curious fact which may be mentioned in connection with the Trinity sands is that metallic iron is found in them in small quantities in various localities. The origin of this iron, which has practically the composition of meteoric iron, and shows lines similar to the Widmanstaetten when carefully etched, has not been determined. It occurs in various forms, some of it appearing perfectly bright, as though just polished, but the greater part has a slight coating of clayey material and a reddish appearance. Analyses of different specimens differ considerably; but it is principally metallic iron, with various percentages of nickel, copper, platinum? and perhaps other metals.

The beds also contain local deposits of lignite, which are, however, not of any value, because of the quantity of sulphur they ordinarily contain.

In the Trans-Pecos region these sands are probably wanting, although there are certain quartzites immediately underlying the Comanche Beds which might be doubtfully referred to this division but for the impracticability of separating them from the other exactly similar quartzites of seemingly earlier periods, such as the surface rocks of the mountains of the Sierra Blanca group. If further investigation shows the entire series to be of this age (which is considered very doubtful), it will give it a very considerable thickness in this region.

The Lower Cretaceous or Grand Prairie Series contains within its area great quantities of very valuable building material—not only building stones, but the very best materials for lime and Portland cement—which must sooner or later meet with proper appreciation. While its soils are, as a rule, not as rich as those of the Upper Series, it nevertheless comprises much valuable farming land and lands that can be made available for farming purposes after a proper study of their character.

Up to this point, if we except a part of the Lower Cretaceous, we have been dealing with deposits, which, for the most part, were laid

down under those waters which, in their present restricted basin, we call the Gulf of Mexico.

The decided break between these formations and the older ones which are found to the north and west, the difference in their dip and the manner of their deposition, is sufficient warrant for the appropriateness of the name of Gulf Border Formations for that part of the Cenozoic group within the limits of this ancient shore line, which, as we now know it, extended from Montague County, on Red River, to Travis County, and thence west, along the Balcones, towards the Rio Grande. The establishment of this shore line was the result of certain earth movements which took place before and during the Lower Cretaceous Period, and which were accompanied by volcanic disturbances, plain evidences of which still remain in the hills of basaltic material scattered from Austin to the Rio Grande, which marked its close. Pilot Knob, nine miles south of Austin, is one of these ancient volcanoes, and there are numerous others that could be mentioned.

There is a strong probability that prior to this disturbance the area which we have described as now occupied by these newer (Cenozoic) deposits was an area of dry land, enclosing a great inland sea, which stretched away, from what is now Burnet and Llano counties, to the north and west, with possible connections with other similar waters in those directions.

The data at hand are insufficient to generalize too broadly on this at present, but the entire character of the formations of what has been designated the Central Palezoic Region, and which is the continuation of the Central Basin of the United States, seems to demand the existence at times of just this shore line of a great land area to the south and east, as a source from which such materials as we find in their composition might be derived.

THE CENTRAL BASIN FORMATIONS.

Having then passed from the coast inward, until we have crossed these descending series of the Cenozoic, we reach the Central Paleozoic Area, with its nucleus of Archæan rocks, and here the usual order of description can be best resumed, for as we pass on to the northwest the various systems appear one after another in due chronological order.

ARCHÆAN GROUP.

The great corner stone, around which the forces of nature, in their work through former ages, have built up the grand empire we now call Texas, is found in a plateau of granite and gneiss, which forms a prominent feature in the topography of Llano and Burnet counties. It has always been the bulwark of the land. It has withstood all storms, the earthquake, and the subtle corrosion of the powers of the air; and although it may be greatly diminished in size since first it appeared as dry land above the earliest seas, where it arose either as an island or, as is most probable, as a part of a great mountain chain or elevated plateau which stretched northward toward the Lake Superior region and west toward the Pacific, it nevertheless does stand, as it has always stood, a most enduring monument of the earliest dry land area of which we have any knowledge.

BURNETAN SYSTEM.

These rocks, which we have called the Burnetan System, occupy an oblong oval area, stretching from the western part of Burnet County into the eastern part of Llano. It comprises a series of gneisses, granites, etc., the present outcrops of which occupy two broad elevated belts running a little north of west (north 75 degrees west), with such outlying peaks and ranges as Niggerhead, Babyhead, King Mountain, etc.

Certain facts suggest the probability that the present shape of this nucleal area is different now from that in which it was first uncovered, and that, as has already been stated, it formed a part of a range or plateau running toward the north, and after its emergence it was folded by dynamic influence into its present trend. This system is divided into three series, which are, beginning at the lowest or earliest, a series of gneisses and granites and allied rocks, which are called the Lone Grove Series, resting on which we find certain schistose rocks, consisting of hornblende, pyroxene, etc.; others containing garnets, and in addition to these the steatite or soapstone, actinolite, etc. These are well exposed at Long Mountain and named therefor. Above these occur other schistose rocks, composed of minerals containing much larger percentages of silica (mica, chlorite, and talcose schists), with bands of quartzite, such as are seen at Bodeville.

These two latter series are found in the synclinal basin or trough between the belts of the Lone Grove granites and gneisses, as well as on

the outer edges of these belts, and were all formed previous to the folding of this system and are affected by it.

The question of the manner of the formation of these lower gneisses is still unsettled. If they were originally deposited as sedimentary rocks, and altered to their present condition by subsequent action of the combined forces of heat and pressure, the change has been so complete as to leave few signs of their sedimentation; but of their eruptive origin there is even greater doubt.

That many of the accompanying granites and other rocks were eruptive is clearly proven, and the time of their eruption is frequently determinable. In the eruptions which occurred while this was a part of the only land area, we find, in the shape and character of crystals which resulted, unmistakable evidences that the molten materials cooled under considerable pressure. The great quartz beds are of this age, as are also the graphic granite or *pegmatite*, and certain binary granites which have very little mica. It may be, also, that the schists of the Long Mountain Series are of eruptive origin, although this is uncertain.

FERNANDAN SYSTEM.

After the folding and the arrangement of the rocks of the Burnetan System in their present condition they formed an island, or more probably a great headland, in an ocean that spread around them on the north, west, and south, in whose waters were deposited the rocks of the succeeding system, which is called the Fernandan.

The evidence supporting the theory of this headland is found in the character of the sediments of which the succeeding rocks are composed. In Llano County they stretch in broad belts in several parallel folds, but their original extent has been greatly diminished by denudation. The indications are that the greater part of this system has, like the Burnetan, always been a dry land area since its first elevation from the Fernandan Sea.

The general strike of the rocks of this system is approximately northwest. The rocks composing it are a series of tough hornblendic schists, less crystalline and containing more quartz, and of more slaty structure than the similar rock of the underlying Long Mountain Series, which, with the Bodeville schists, formed the shore line of the ocean, and furnished the materials for the formation of these rocks and of the overlying mica schists, which together form the Valley Spring Series.

Above this is found the Iron Mountain Series, consisting of a fine-grained quartz rock with scales of mica, which underlies the great bed of magnetic iron of which so much has been written; and this is overlaid by the Carbonaceous schists, graphitic at the base and carbonaceous and shaly at the top, which gradually blend into the slaty chloritic schists overlying them; and thirdly, the beds of dolomitic marble of the Click Series, whose present state of metamorphism marks the great change that has taken place since their original deposition as limestones. This system also had its characteristic irruptions of granites and granulites and quartz, and the final movement gave it its present general trend of northwest and southeast.

In the Trans-Pecos Region the granites of the Quitman and Franklin mountains seem to be referable, in part at least, to this period. Their lithologic character and general trend, as well as their relations to strata of later date, seem sufficient warrant for such determination, but the complications arising from the masking of these relations by the great deposits of Quaternary age which surround them have always been a cause of trouble in the determination.

EPARCHÆAN GROUP.

TEXAN SYSTEM.

The next great system which was deposited around and upon the Fernandan is called the Texan. As the Fernandan was in a great measure derived from material provided by the denudation of the Burnetan, so this system had its origin in great part in sediments derived from both these earlier systems. The present areal distribution of its exposures in the Central District is in three principal belts running north and south through Mason and Llano counties and west of the Colorado River, which seems to have been somewhere near the old shore line of these seas. The first or eastern of these areas is south of Long Mountain, and covers the region west of the river to Packsaddle Mountain. The second is west of Riley Mountains; and the third, about ten miles in width, stretches still further west to Katemcy and Mason, and the rocks included in this system show no effects of any uplift prior to that north and south, although they are badly broken and faulted by later ones. The rocks are principally siliceous, beginning in the Mason Series by sandy shales and schists with mica, passing into quartzites and sandstones in the Llano Series, and shaly beds and marble in the Packsaddle Series. To this system (Texan) we may

also refer a series of rocks of a similar character and trend found in the Trans-Pecos country, in the vicinity of Eagle Flat and the Carrizo Mountains, the areal extent of which is as yet entirely unknown.

This system, beginning in a condition of shallow seas, shows by its manner of stratification, the layers of basic materials that occur in it, and the local differences in sections, that it had a vacillating border. In the Llano Series eruptive rocks were interbedded near its close; but during the Packsaddle epoch deeper water prevailed, probably until the upheaval which gave the rocks of this entire series their present north-south trend. This system closes the first great era of the geologic history of this region—a period marked through the three eras we have described by conditions of depositions, interrupted and broken by great eruptions of igneous matter, which appear to-day interbedded, or as intrusions, or as smaller and larger dykes. According to the materials of which they were composed and conditions of eruption, they are now granites of various kinds, certain basic (hornblendic, etc.) schists, feldspars, quartz, etc.; and after their final elevation the materials which erosion has taken from the rocks of these systems has always formed a part in the formation of the systems that overlie them.

Perhaps there is no place where there is a stronger illustration of the necessity for the careful study of the structural geology, as a basis for accurate economic work and determination, than is found within the region covered by the rocks of the three great systems just described. For years this Central section has been held forth as a rich mineral region. The evidence of the occurrence of ores is plainly discernible by any one examining the district. The surface indications are plentiful, and often a single blast will show lumps and nodules of less or greater size of grey or peacock copper. In spite of this, and although much money has been spent in prospecting, no success has been obtained in mining, because the real relations of the ore bearing veins to the general geology were not understood on account of the various complications caused by the different uplifts, and could not be ascertained without more detailed work than had ever been given it. The search was, therefore, in most cases a haphazard one, and nothing practical came of it. The facts gathered by the survey greatly alter this, and we are now able to present them in such manner as will greatly assist the practical miner in his work.

We have definitely associated the various veins of silver, copper, lead, iron, and manganese, each with its proper series of rocks, and the care-

ful prospector will now know where to expect such ores, and also where they can not exist. Connected directly with the three systems already discussed, we find the copper ores, with their variable associations of silver, and possibly a little gold, and the magnetic and other iron ores, whose extent and richness will yet be one of the crowning glories of the district.

GOLD.—The prospect for the finding of gold deposits in this region, in quantities of any economic value, is very slight. It *may*, however, be found in variable quantities associated with other ores.

SILVER.—Silver is found in the rocks of the Burnetan and Fernandan systems with ores of lead and copper in veins; and, while the bodies of ore which have been found up the present are not large, the quality of the ore is sufficient to warrant a more careful search under skilled advice and with modern mining appliances.

COPPER.—These silver ores, as has been stated, are associated with galena and copper. Very little of the galena belongs to these series, but the copper ores are found principally in these rocks. Their presence is most plainly observed when rocks of the Burnetan and Fernandan systems in their regular east-west course are crossed and broken by the north and south rocks brought up by the Post-Texan uplifts. This very fact complicates the vein formations, and renders a study of these three systems and their accompanying eruptions an absolute necessity for the proper economic working of these ores.

The surface indications of copper ores are the green carbonates of copper which appear so plainly in the rocks, and in a few cases even grey and peacock copper have been found at the surface in stringers of quartz. Analyses of the ores taken from different prospects show that the quality is sufficiently rich to justify the thorough investigation of the outcrops and the sinking of deep prospect shafts.

MANGANESE.—Another very valuable ore of this group is that of manganese, which occurs in the Fernandan trend, *i. e.*, northwest-southeast (magnetic). The value of this ore in steel making is very considerable, and the indications are that other bodies similar to that at the Spiller mine will be found when proper investigations are set on foot. The ores at the Spiller mine can be procured in quantity and quality sufficient to make them marketable.

IRON.—As has already been shown in the general section of the Fernandan System, one of its most persistent strata is a bed of magnetic iron ore. While it cannot be stated at present that there is one con-

tinuous bed or series of beds, it is nevertheless a fact that even if the bed seems to be absent at any point in its proper strike, there still remains an indication of it in a line of ferruginous soil or other landmark. The beds in which these ores are found occur over an area some twenty by thirty miles square, and from the description of the position and character of the Iron Mountain series of rocks, they can be easily located. There are several belts in which they occur: the Babyhead, Llano, Iron Mountain, Western, and Gillespie. In the first two little or no prospecting has been done, but the third has been opened in two localities by diamond drill holes and by a shaft and cross-cut. Of the quality of these ores nothing can be said more than has already been stated many times. They are of extreme richness and purity, and in sufficient quantity to be of great commercial value. That they must become of great value to the section in which they occur, and to the State as well, is a certainty.

In addition to the various ores, these formations contain many other substances of great economic value, of which only a few will be mentioned here. Foremost of all, perhaps, we have the great deposits of granite, which vary from those which are easily decomposed, and therefore only suitable for road material, to those of greater hardness and beauty, well fitted for the most elegant architectural and ornamental uses. The soapstone will also be of considerable value, as it exists in quantities and of excellent quality. Some of the slate may prove useful for roofing material. The graphite, although too impure for finer uses, may be found sufficiently pure for commoner purposes.

PALEOZOIC GROUP.

CAMBRIAN SYSTEM.

With the beginning of the next system, which is the lowest one of the Paleozoic Group, new conditions existed, and the remains of certain forms of life appear in the rocks. This system, the Cambrian, was deposited in this area in a basin of limited extent, whose western border was probably somewhere to the west of Llano. Here, under the varying conditions of shallow water and earth oscillations, there were laid down three series of strata—the Hickory, Riley, and Katemcy.

THE HICKORY SERIES.

The lower of these is found well developed at House Mountain, in the valley of Hickory Creek, and at other places. The rocks included in it are a coarse conglomerate at the base, which becomes finer-grained toward the top, and folded into several broad folds by granitic upheavals.

THE RILEY SERIES.

Lying unconformably in the synclinal valleys thus produced we find shallow water deposits (sandstones) of various colors, which were formed directly from the detritus of the underlying rocks. These constitute the Riley Series, and often contain iron deposits of sufficient richness to be of value as ore. It is in the rocks of this series in which we find our first evidences of animal life in the few fossil remains which occur.

THE KATEMCY SERIES.

The Riley Series is in its turn overlaid by a series of beds called the Katemcy, which has a very wide distribution in this area, and which corresponds to the "Potsdam" of all geologies. The rocks of this series show a gradually deepening sea, and begin with a sandstone of a red color, overlaid by white, and that by a friable greensand bed, which together are known as the Potsdam Sandstones. Above these we find in many places a series of greenish shales and sandy limestones, to which we give the name of Potsdam Flags. As the subsidence continued a bed of limestones was laid down upon the shales and flags, or upon a conglomerate formed of them, by the water of the sea. These Potsdam Limestones are in many places impregnated with particles of greensand.

The disturbance which had marked the course of each preceding system were continued throughout this one also, but with somewhat diminished power, until finally the system was brought to a close by the elevation into a land area of a large portion of it on the west. The beds of iron ore which have been mentioned above, are results of alterations of the magnetites already described under the Fernandan System. They are chiefly segregations in the sandstone, and bonanzas of these ores seem to occupy zones following the trends of the magnetite belts. These ores, beside being valuable for the iron they contain, may

also in many cases prove of still greater value in indicating the presence of the bed of magnetite from which they were originally derived.

Other similar ores are found showing still further alterations and the addition of water, but while such ores are somewhat abundant, richer ones will probably prevent their being brought into use.

SILURIAN SYSTEM.

The next system, the Silurian, began with shallow water conditions on the west of the Central Mineral District, followed by a subsidence, during which conditions the strata of the Leon and San Saba series were deposited.

THE LEON SERIES.

The Leon Series consists of sandy, shaly buff and sometimes yellow dolomite, overlaid by beds of siliceous magnesian limestone. These rocks have two distinct methods of weathering, the lower containing numerous caves, while the upper forms steep bluffs. These are followed by the compact limestone of the Hoover Division. This widespread series of rocks, some of which are better known as Burnet and San Saba marble, lithographic stone, etc., is found both in contact with the other strata just described, and also upon various horizons of the Potsdam sandstones and limestones. They consist of fine-grained, compact limestones, or white and gray dolomites. At the base of the series they contain a large number of fucoidal remains, and become finer-grained, and thicker and purer as we ascend, until toward the close another elevation of the sea bottom gives us fine-grained, gritty dolomites, now of crystalline texture.

THE SAN SABA SERIES.

The San Saba Series, which overlie these and form the upper beds of the Silurian System, consist of dolomites and chert, and it is from these that much of the material for later conglomerates and sandy shale is derived. The rocks of the Silurian are therefore limestones and dolomites, which in many cases have been metamorphosed into marbles or semi-marbles. They are found surrounding the entire Archæan area, and recent investigations point to their possible continuation westward (under the cover of the Cretaceous rocks) to the mouth of the Pecos, and it is quite probable that they formed the eastern shore of the interior sea also. They are also found well developed on the eastern flank of the Franklin Mountains, near El Paso.

The life of this period was abundant. Besides the plentiful remains of various shell fish, crustaceans, and fucoids, we have great beds of fossil sponges. Its economic importance is due to the beauty of its marbles and its ores of lead.

The lead deposits belong principally to this system (Silurian), and while exact correlation can not be made on the basis of present knowledge, the close relationship to the galena limestones of Missouri, Illinois, and Wisconsin is proved. Therefore, the prospector for lead has to watch the occurrence of the rocks described under this system, and having familiarized himself with them, he can confine his work to localities in which he finds them outcropping, and thereby save himself much useless labor, and it is possible that systematic prospecting will bring to light large and valuable deposits of this ore in the limestones of this period. This period, like former ones, was also subject to earth movements, and after its close a great movement broke it in various lines along a trend north 25 degrees east.

DEVONIAN SYSTEM.

The beds above these, which are found to consist of yellow shaly dolomitic material, have fossils which are closely allied to Devonian forms, and the strata are therefore so classified, subject to the final conclusions based upon the facts to be ascertained during the coming field season.

CARBONIFEROUS SYSTEM.

The exposures of the formations, from the beginning of the Archæan through the Devonian, are confined, so far as critical study has gone, to the Central Mineral Region. To the north and west of this we have a great series of the later Paleozoic sediments which are now exposed, principally at least, by the erosion of the Lower Cretaceous strata which at one time overlaid them.

In most places the rocks found underlying those of the Carboniferous belong to the Silurian or even older systems. This is the case not only in the eastern border but on the eastern side of the Franklin Mountains; and on the mountain at Eagle Flat the Upper Carboniferous limestone rests directly upon the upturned edges of the Texan schists. This contact with the underlying rocks is always unconformable and often shows the folding and even erosion that took place before their deposition.

So far as we now know, the Devonian, which is the system immedi-

ately preceding the Carboniferous, either existed only in limited areas or has been almost entirely destroyed by erosion.

It has been stated that the character of the deposits found along the eastern and southern borders of the Central Paleozoic Region is such as to almost necessitate the existence of a shore line from Red River to the Colorado and west to the Rio Grande—possibly in some such locality as the present western and northern border of the scarp of the Grand Prairie plateau.

From this shore line of the great land area which existed to the east and south a sea stretched out towards the west and north.

The present outcrops of this interior sea appear east of the Pecos in a series of beds whose boundaries have a general northeast-southwest course, and as we go northwest or across the strike of the formations we gradually rise both topographically and geologically. The beds are alternations of sands, sandstones, clays, limestone, and shales, with coal and gypsum; and this alternation of strata of hard and soft materials gives us a rolling country of great beauty. The ascent to the north and west is not a gradual slope, but rather a series of steps. This is due to the harder layers of rock material which occur scattered through the softer material. The steep side, or bluff as it often shows in places, is commonly towards the south and east, while the gentle slope is more nearly in the direction of the dip. Exceptions to this are, however, numerous, caused by the various drainage channels of creeks and by other local conditions. The capping of the Cretaceous rocks which also exist in parts of this region aids in bringing about other changes in the general topography. The whole region is one of great erosion, and until this shall have been studied and properly understood we will be unable to fully appreciate all of the features which its present topography force upon us. To the west of the Pecos the rise is very rapid, and the underlying Paleozoic rocks are covered in most places by the Cretaceous until we reach the southern continuation of the Guadalupe Mountains at Van Horn, where the Carboniferous rocks are again brought to view.

In this great interior sea were laid down not only those sediments which now constitute the Sub-Carboniferous and Carboniferous, but also the Permian, and it may be the Jura-Trias strata—or, in short, all those previous to (and possibly even after) the beginning of the Cretaceous period. These various sediments show little signs of disturbance other than the deepening or shallowing of the bed of the sea itself, save just along the ancient shore line, and are usually of a very gentle dip.

The western border of the sea was certainly not beyond the Franklin Mountains. For the present synclinal, which includes by far the greater part of these formations, is limited on the west by the Guadalupe Mountains, and, although the elevation of this range was in Post-Paleozoic times, they may have formed the western shore. Other remnants of the same rock series exist between these mountains and the Franklins. This synclinal valley has an average width of over 300 miles, and the eastern edge of the basin has an elevation of less than 800 feet, while the same strata on the west are fully 4000 feet higher. This gradual rise, which averages only 12 feet to the mile if the entire distance be considered, is in fact much more rapid toward the west.

The deposits in the early Carboniferous Sea show a condition of comparatively deep waters at its beginning and the deposition in them of limestones of considerable thickness, followed by shallower water and shaly beds with a great number of characteristic fossils. In places these lowest limestones and shales seem to show an unconformity of deposition with the overlying sandstone; and for this reason, and the finding of a species of fossil shell which is considered characteristic of the Sub-Carboniferous, it was supposed that these beds might belong to that period. A careful examination of the fossils seems to point to a preponderance of coal measure forms, however, some of which are as characteristic of that period as the first named was of the Sub-Carboniferous. The final determination must therefore await more careful stratigraphic and paleontologic work than has yet been done. The beds contain one or more thin seams of coal, but neither of them are likely to prove of any commercial value; but its beds of carbonaceous shale may prove to be a reservoir of gas or oil at some point north of its outcrop along the San Saba River. As this formation is well exposed at McAnnelly's Bend, in San Saba County, it will be known as the Bend Series.

THE RICHLAND-GORDON SANDSTONES.

The rocks of the undoubted Carboniferous begin on the eastern border by a series of sandstones of such character as imply the existence of littoral conditions at no great distance. In the Colorado coal field these sandstones, with the underlying clays and sands, are given the name of Richland Sandstones, and in the Brazos coal fields sandstones of similar position and composition have been named the Gordon Sandstones.

These sandstone beds are practically barren of coal, and merely mark

the beginning of conditions favorable to the growth of the coal plants, many remains of which are found preserved in the strata.

MILBURN-STRAWN SERIES.

Immediately overlying these sandstones and sands and clays we find the Milburn and Strawn series. These beds are composed of alternating clays and shales and thin-bedded limestone with fire-clay and coal. In the Colorado field only one seam is known, and that begins in the southern edge, in a bed of coal shale, which gradually changes to a thin seam of coal as we go northeastward along its strike, until in the vicinity of Gordon and Strawn it has developed into a bed of coal of great economic value.

This difference of condition favorable to the deposits of coal in the two divisions of the Central Coal Field (the Colorado and Brazos) is especially marked throughout the entire series. Thus, in the Brazos field there have been no less than six coal seams observed in the beds which constitute the Strawn Series. These seams of coal, in their southern exposure along the Texas and Pacific Railroad, show a thickness of from one to thirty-six inches, and it is possible that when some of the thinner beds are systematically traced toward the northward along their outcrop that they may also be found to become of workable thickness.

The beds of corresponding age to these seem to be wanting in Western Texas, except in the Eagle Mountains, and then they are so disturbed and faulted by subsequent porphyritic materials that their real position has not been positively determined.

COAL.

The coal of the Strawn Division, especially of coal seam No. 1, which has been opened in a number of places along its eastern exposure, is well adapted for fuel purposes. Some of it makes a fine coke in the laboratory, but no systematic attempt has been made to coke it in ovens, so far as our present information goes.

This coal seam outcrops through Erath, Palo Pinto, Wise, and Montague counties, and can be reached west of its line of outcrop by shafts. The coal is in use upon the railroads and for fuel generally. The other seams of coal in these beds are much thinner, and so far none of them have been observed of workable thickness.

BROWNWOOD-RANGER SERIES.

This condition, so favorable for the production of coal, was followed by an epoch of alternate deep and shallow water, during which were deposited the limestones and sandstones of the Brownwood-Ranger divisions. In these beds there is a considerable amount of salt, some oil, and a little gas, but no commercial use has yet been made of them.

WALDRIP-CISCO SERIES.

These beds are succeeded by another series of coal beds—the Waldrip-Cisco Beds. In them is repeated in great measure the characters of those already described, as far as their lithology is concerned—beds of alternating clays, shales, fire-clays, and limestones, with seams of coal of varying thickness. So far two seams have been noted in these beds in the Colorado field, while there are three in the Brazos. The coals of these beds seem to be considerably more sulphurous in some localities than in others, but in no place have there been sufficient openings made in them to prove what their value would be away from the part already affected by surface decomposition and the action of surface waters.

These seams outcrop from Waldrip, at the Colorado River, in a north northeast direction to Montague County, and there is but little doubt that the careful investigation now being made of them will show many places where deposits of great value exist.

COLEMAN-ALBANY SERIES.

The deposition of these coal beds was followed after a time by a condition of muddy waters, in which were laid down beds of shales, clays, and limestones of the Coleman-Albany Division, which, so far as investigations have gone, are barren of coal.

With the close of this series ended the deposition of the materials now placed among the Coal Measures proper.

The rocks of this system west of the Pecos River are not sufficiently known to divide them into series and finally correlate them with the beds just described. In the Guadalupe Mountains we have an exposure of about three thousand feet of Carboniferous strata in three distinct series. The lower beds are dark limestone, without fossils, as far as observed. Overlying these are fifteen hundred feet of yellow quartzose sandstone, with bands of limestone, and containing

coal measure fossils. This is capped by one thousand feet of white limestone with many fossils, some of which are the same as those found in our upper coal measures, but numbers of others have been described as belonging to the period which follows. Lithologically, we have here a base corresponding to our Bend Series, followed by a great thickness of sandstone and bands of limestone covering the period of our entire coal series, showing that at this region the sea bottom remained at a more uniform depth.

The upper limestone corresponds in its lower part to the Coleman-Albany Beds, lithologically, and also in the fossil remains. The Carboniferous limestone of the Eagle and Diabolo mountains, so far as they have been determined, also seem to belong to this horizon. Coal occurs in this district, but its extent is unknown, and where examined does not promise much.

The rocks, therefore, which comprise the strata of the Carboniferous System show by their composition and character a sea of varying depth, with land conditions to the east and south. The life was very abundant, great numbers of fossil shells being found throughout the different series of beds; remains of coal plants are plentiful, and some fragments of vertebrates have also been found. These beds differ from the deposits of the Tertiary, in their continuity especially. In the latter formation a bed of sand alters in a short distance to a bed of clay, and the lignitic coals exist in lens-shaped masses, while in the Carboniferous all these are more persistent, and while a seam of coal may vary in thickness it very rarely is wanting altogether, unless from erosion.

In addition to the great value of the beds of this system to our State for the coal they contain, they are equally valuable in their other economic aspects. They contain large deposits of admirable building stone, some of which is altered into a compact limestone or semi-marble and takes a very fine polish. Even the coarser kinds make good dimension stone, and are used all through the district in which they occur. The sandstones are also used to some extent. In connection with the coal we find large deposits of very valuable fire-clay which must when properly developed be of great value. Clays for brick and pottery-making exist also, and sands for mortar are abundant.

The soils of the Carboniferous are varied as the alternating strata

from which they are principally derived, and are as varied in quality as in kind. Many of these are very fertile and produce good crops.

At the close of this period the southern shore line, which had probably been somewhere below the 31st parallel, was moved northward by the elevation of the old sea bottom into a land area, and its surface was in turn exposed to erosion, and the results of this denudation went to form the deposits of the succeeding system, which we know as the Permian.

PERMIAN SYSTEM.

WICHITA BEDS.

The Permian deposition is marked by three distinct periods. In the first of these beds the shore line was probably not far south of the present Brazos River channel in Throckmorton and Baylor counties, for no deposits of the Wichita Beds are found south of that point. The rocks are sands and clays with many concretions—siliceous, ferruginous, etc. In places copper ore is found in greater or less quantity, principally as a pseudo-morph after wood; sometimes, however, as nodules or segregations. And here are also found in the different strata the remains of many vertebrates and plants.

CLEAR FORK BEDS.

Following the deposit of this division of the Permian, the sea gradually encroached upon the land and drove the shore line southward beyond the Colorado River in Concho County, and the Clear Fork limestones and underlying and overlying clays and sandstones were laid down therein. Some of these limestones are more or less argillaceous; all are magnesian, and in some of the upper seams they carry small quantities of galena scattered through the occasional bands of limestone. Toward the upper portion these beds also contain some gypsum, and thus mark the advancing conditions of the Double Mountain Beds.

The clays and sands of these Clear Fork Beds are all more or less calcareous, and contain gypsum in small quantities, and the resulting soils are therefore of great fertility. The life of this age, as shown by fossils, was principally of shell fish and corals in the earlier portion, while in the upper we find plants and vertebrate remains and the tracks of articulates.

In these upper strata also we find other deposits of copper similar to those of the Wichita Beds. In one locality, near California Creek, we found the remains of a tree, a portion of which was cuprified while the balance seemed to be silicified.

DOUBLE MOUNTAIN BEDS.

The shoaling of the water continued until the time of the Double Mountain Beds was ushered in. These show a series of land-locked shallow seas, which were subject to periodical overflows from the wider ocean, and in which were deposited the beds of gypsum and rock salt, the sands and clays, the sandstones and shales that go to form the rocks of this division.

The rocks stretch with very gentle dip towards the northwest until they are hidden under the Plains deposits. The greatest element of wealth within the region covered by this system is its grand soil. The Abilene Wichita country, as it is called, which was in former times supposed to be so far within the arid region as to be practically worthless, has proved on actual trial to have sufficient rainfall to mature the finest crops under intelligent farming. From the very origin of the soils and the constituents they receive from the underlying rocks, great fertility is assured, and since the rain has proved sufficient it would seem impossible to predict too bright a future for its agriculture. It seems destined to be the great wheat and small grain region of the State, although other crops also do well. The other principal materials of economic value consist of excellent building stones, which are found in the beds of limestone and sandstones, some of the latter being of a most beautiful light red color, fully equal to any that is brought to the State for trimmings or fronts for buildings; the great beds of salt, some of which, like that at Colorado, are 100 feet thick; the deposits of gypsum—embracing all known varieties and of all states of purity, from a gypsiferous clay to alabaster and selenite—which exist in really inexhaustible quantities, and will be used for fertilizing or the manufacture of plaster of paris, and for many ornamental purposes; and the copper deposits, which will sooner or later become of some value.

With these Permian Beds the great group of deposits classed as Paleozoic ended. The fauna which characterizes the Permian shows clearly, by the intermingling of the older and newer forms of life which are there found together, that it was a transition formation, and it is probable that at the close of this era this entire area was elevated into dry land and remained such during the early part of the Mesozoic era, for so far we find little evidence of the existence of the lower systems of that group.

MESOZOIC GROUP.

JURA-TRIAS.

The only rocks which now seem referable to the Jura-Trias, which covers the period between the Permian and Cretaceous, are a fine-grained red (terra-cotta) sandstone, which underlies the Trinity sands in the Double Mountain, Stonewall County, and the conglomerate and sandstone which have been called the Dockum Beds, from their characteristic exposure at that point. This conglomerate is the water-bearing bed of the Staked Plains. From it flow the great springs that feed the Red, Brazos, and Colorado rivers, and from which they take their rise, and their corrosive force is the power that is gradually eating into the scarp of the plains and moving them backward year by year. The greatest value of this bed is its water bearing quality, and it was thought that enough fossils were collected from it to enable us to correctly determine its age and exact relations to the other strata. For the present it is placed with the Terra-Cotta sandstone above as Jura-Trias, as it underlies the Trinity sands.

The deposition of these beds was followed by the opening of the Cretaceous System, as shown in the Trinity sands, the accompanying conditions of which may possibly have been the initial depression forming the Mississippi embayment, the extent of which was greatly diminished in Mid-Cretaceous times by the elevation which brought the greater part of the Lower Cretaceous to the light of day. From this point we have already traced the history of our State with the exception of the deposit which forms the upper portion of the Staked Plains.

This deposit, called here the Blanco Canyon beds, is composed of white clays, infusorial earth, etc., containing fossil remains of vertebrates (turtles and large animals). In age it probably corresponds to to the upper part of the Fayette Beds, which it resembles closely in some lithologic features.

The geology of Trans-Pecos Texas cannot be discussed at this time for lack of detailed knowledge.

ARTESIAN WATER.

From what has been written it can easily be gathered that our salient geologic features may be comprised in—

A Gulf Slope.

A Central Basin.

A Western Mountain System.

Each of these has its definite relations to the chances for artesian water supply. In the Gulf Slope, which embraces what has been called the Gulf Border Formations, we have four artesian water belts, or sources of artesian supply, viz: The Trinity Sands, the Lower Cross-Timber Sands, the Fayette Beds, and the Carrizo Sandstone on the Rio Grande border. The Trinity Sands will furnish artesian water to all that country between their eastern border and the Basal Clays of the Tertiary (if no more), provided the topographic features are favorable, which is the case over the greater part of the area. This water is only partly mineralized, and by proper casing it seems possible to secure water well suited for ordinary uses. The depths at which it is reached vary from 100 to 2000 feet, which is the deepest bore of which we have any record.

The area in which water will be furnished by the Lower Cross-Timber Sands is much more limited and local, but its extent is governed by the same principles as the other.

The Fayette Beds will furnish water to the entire coast country. Owing to the amount of pyrites and other mineral matter they contain the water will be more or less mineralized wherever the bore is any great distance from the outcrop of the beds, while near the outcrop the water secured from them is found free from minerals.

The Carrizo Sandstone will doubtless supply water to much of the Nueces and Rio Grande valley below Eagle Pass. Wells have already been bored to strike all these beds, and there is no longer any doubt as to their availability.

In the Central Basin both the topography and character of the rock material seem to favor the finding of artesian water in many localities. Natural artesian water occurs in the many springs found from Lampasas westward, and numerous wells have secured flowing water, both in the eastern border of the basin and at and beyond the Pecos. In this division there are two areas of possible catchment basins which may serve as a source of supply for artesian wells. The first of these is the Richland sandstones, which are slightly topographically higher than a portion of the country they underlie to the north. This is also the case with the southern border of some of the Brownwood beds. Therefore, in some places in the Colorado Coal Field artesian water will be found; *but not fresh water.* In common with most waters found in this basin it will be saline, as is clearly proven by such wells as are already flowing. The amount of salt contained in

these will, however, vary greatly, but must in many places be too great to permit their use for any other purpose than the manufacture of salt.

While the general dip of the strata is northwest, and under suitable conditions the outcropping edges of the eastern sandstones would prove a source of supply to the country west, the rapid rise of the country forbids the hope of securing flowing water from that source. It may be, however, that the conditions of the southern border may be repeated in greater or less degree by the elevation along the the northern border, and this is probable. The only other catchment area which can be looked for must be in the elevated country beyond the Pecos, where these strata again appear. Such a basin is found in the valley of the Guadaloupe Mountains, stretching southward to Van Horn. In this deep valley, filled with eroded material to a depth of 800 feet as is shown by the wells at Van Horn, we find the outcropping of the Carboniferous sandstone, which dipping gently to the southeast carries this water so that it is reached at Toyah, fifty miles distant, at 800 feet, and there yields a fine flow. This water could also be found at Pecos City, were it worth while boring to a depth sufficient to reach it, but that city is supplied with water from the artesian wells which find their source of supply in beds of the same horizon, seemingly, as the Trinity Sands. The water at Toyah, like all that so far found in the Central Basin, is salty, and the character of the rock materials and the included minerals lead to the conclusion that fresh water can not be had from artesian wells in the Central Basin, except within very limited areas, which, from local topographic causes, might yield such water at moderate depths. As yet no such localities are known.

In the mountain region the prospects for artesian water are not good, for reasons which have been fully given in the description of the country. The water is collected in the great valleys of erosion, and must be reached by wells 800 to 2000 feet deep, and lifted the greater part of the distance by pumps. These are the general conditions. Those of separate localities which may or may not prove favorable have not yet been examined.

This brief statement of the character, extent, conditions, and contents of the various formations, which taken as a whole form the basis of the life and wealth and culture of the Lone Star State, is compiled for the most part from the results of the work done by myself and the members of the Survey during the fifteen months of its existence.

The details of the various formations and the facts upon which many of the statements are based will be found, stated at such length as the time at our disposal would allow, in the various papers accompanying this Report.

PERSONNEL.

In the table given herewith will be found the names, dates, and character of employment of all who have been connected with this Survey since its beginning, except field assistants:

	Date of Appointment.	Date of Resignation.
Commissioner—		
L. L. Foster	....	....
State Geologist—		
E. T. Dumble	Sept. 21, 1888	....
Geologists—		
W. H. Streeruwitz	Sept. 29, 1888	....
W. F. Cummins	Oct. 1, 1888	....
R. A. F. Penrose, Jr	Nov. 10, 1888	....
T B. Comstock	June 20, 1889	....
R. T. Hill	Feb. —, 1889	....
Assistant Geologists—		
C. C. McCulloch, Jr.	Oct. 10, 1888	....
G. Jermy	Nov. 10, 1888	*Dec. 10, 1888
J. L. Tait	Nov. 10, 1888	Dec. 10, 1888
John Owen	Nov. 10, 1888	Dec. 13, 1888
J. A. Taff	Feb. 15, 1889	....
Chas. Huppertz	Mch. 1, 1889	....
J. B. Walker	April 1, 1889	....
G. E. Ladd	June 1, 1889	Nov. 25, 1889
D. W. Spence	July 1, 1889	Sept. 10, 1889
N. F. Drake	July 20, 1889	....
J. S. Stone	Sept. 23, 1889	....
R. S. Tarr	Nov. 1, 1889	....
Chemists—		
J. H. Herndon	Oct. 15, 1888	....
M. M. Smith	Oct. 12, 1888	June 20, 1889
R. B. Halley	Oct. 14, 1888	May 10, 1889
P. S. Tilson	Jan. 20, 1889	....
L. E. Magnenat	Aug. 1, 1889	....
Topographers—		
J. A. Nagle	June 20, 1889	....
R. Wyschetzki	May 1, 1889	....
K. Giersewald	June 20, 1889	....
Clerks—		
J. L. Jones	Aug. 20, 1888	....
E. W. Cawthorne	Aug. 20, 1888	Oct. 22, 1888
J. E. McGuire	Sept. 28, 1888	....

* Reappointed January 1, 1889.

I submit herewith the reports of the several field geologists, and for the details of their work refer to them.

ACKNOWLEDGMENTS.

The thanks of the Survey are due to the great number of citizens of the State who, by their interest and help, have contributed to the work of the field parties. These favors have been so numerous that it is impossible to make separate mention of them.

To Major J. W. Powell, Director of the United States Geological Survey, this Survey is indebted for many favors, among which may be mentioned permission to make use of the Texas portion of the plates of his new map of the United States, which here appears as our Progress Map.

To Professor T. C. Mendenhall we are indebted for the use of the base-bars used in measuring the base line in Trans-Pecos Texas.

Mr. G. Browne Goode, Assistant Secretary of the Smithsonian Institute, rendered us great assistance by furnishing plans, photographs, and descriptions for the museum cases and their arrangement in the room.

My own thanks are especially due to the different members of the Survey, who, by faithful and earnest work, have made this Report—so full of detail, and covering such an extent of country—a possibility.

GEOLOGICAL SURVEY OF TEXAS.

REPORTS OF GEOLOGISTS.

1889.

REPORT OF MR. W. VON STREERUWITZ.

AUSTIN, TEXAS, March 31, 1890.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—The portion of the State to which my field work was confined during the year 1889 is that extreme western part, embraced between the Pecos River and Rio Grande, known as Trans-Pecos Texas, and the time I was in the field was devoted principally to preparatory work and determinations which were positively essential to a correct understanding of its geology. For successful geological determinations and investigations of this part of the country, the study of the topography is absolutely required. Eruptive rock, of different periods and character, intrude into and penetrate the sedimentary strata, which are also of different ages, and for the most part strongly metamorphosed.

The mountain groups and ranges and the hills are separated from each other by wide gaps and extensive flats, filled in with more recent deposits, which adds greatly to the complications of the geological work in this part of the State.

Another source of complication arises from the great erosion of the older mountains by the Cretaceous sea, as well as from later erosions and intrusions, and the covering of these by more recent materials after the Cretaceous deposits were formed.

The information which can be derived from former records is meagre and merely fragmentary, for the most part consisting of short remarks or discussions, made more or less general and based on casual or disconnected observations during rapid trips; and consequently, even if the observer were perfectly trustworthy and of undisputed capacity, his information can only be a very limited assistance to more exhaustive geological work.

Existing maps of the counties west of the Pecos River have been compiled mostly from records of old surveys, some of which are of very doubtful value. The mountain ranges, rising precipitately from the extensive flats, are so rough and so steep that running and measuring straight lines across them is almost or quite impossible. The starting point from which such lines are said to be run (on the New Mexico-Texas line) are far distant, and to reach them many obstacles of a serious nature have to be encountered. Adding to this the changes of the needle bearings, the absence of corner monuments, and numerous other difficulties of less importance, which must, however, be met and overcome, it becomes evident that the existing maps and surveys can not be made the base for the determination of mineral districts and other geological work in Trans-Pecos Texas.

These complications made it an essential requisite to begin by preparing a topographical map, on which to lay down the geological features of the country. So, being instructed to begin with the beginning, and fitted out for that purpose, I prepared for taking the topography of the country, starting at Sierra Blanca.

With the aid of an assistant, Mr. Wyschetzki, I began by carefully measuring, with weighted steel tape, a preliminary base line from which to start operations. I then laid down the bench marks for the first horizontal curves, and located, by triangulation, the more prominent mountain peaks of the surrounding country, at the same time obtaining as much information as possible, and collecting specimens from prospects and outcrops.

Later, being provided with the county maps of West Texas, and receiving instructions to classify the mineral lands to be taken from the market and to be reserved for mining purposes only, I began to make such classifications, and to map these out as closely as could be done without previous correct topography and thorough examination of the country. Additions and changes will doubtless become necessary as the geological work progresses.

An additional assistant sent from Austin left after two weeks service for home. He was replaced by Mr. Girsewald, and I then began to map the topographical features of the country in the vicinity of Sierra Blanca by reconnoissance, which, after a careful consideration of surrounding circumstances, I thought the most expedient method.

To secure the necessary water supply for the outfit, I made my camp at Sierra Blanca Junction, from which point I took the topography of the Cretaceous hills and the extensive flat north and northeast of the station, taking the long tangents of the Texas and Pacific and Southern Pacific railroads as a base, and starting the first horizontal curve at an elevation of 4600 feet above sea level.

The vertical distances of the curves were taken 100 feet from each other.

Moving farther west, I extended the tangent of the Texas and Pacific Railroad by a transit line to the foot of the Quitman Mountains, working therefrom and checking the work from this line and by ordinates of the railroad curves. I followed this course in all topographical work until I was furnished with base-bars kindly furnished by the United States Coast Survey. These, however, I did not receive until toward the end of December, although they were shipped from Washington the 26th of September.

From Sierra Blanca Junction I moved the camp to the foot of the Quitman Mountains, or as they were called formerly by the Mexicans, very appropriately, Sierra de los Dolores.

From this camp I took the topography of a part of the Sierra Blanca Mountains proper which lie north of the railroad, the hills and the interme-

diate flats west toward Finlay, and a part of the Quitman Mountains to the south, with the foothills southeast.

The absolute dryness of the Rio Grande, and the absence of springs or other water sources, compelled me to abandon for the time the contemplated removal of the camp to the river; and in consequence the completion of the topography of the Quitman Mountains, and indeed of all the hills, mountains, and flats close to the river and distant from the railroads.

I therefore removed my camp to Eagle Flat on October 15, where I got water, partly from the section house cistern and partly from an old prospect hole in the foothills of the Sierra Diabolo.

From this camp I connected with the topographical work done from Sierra Blanca east, extending the same in a north and northeast direction toward the Sierra Diabolo and to the longitude of Torbert, and east to the railroad track of the Southern Pacific Railroad.

After having removed the camp from Eagle Flat, on the Texas and Pacific Railroad, to the Southern Pacific Railroad, six miles west from Torbert, I began mapping the topography of the foothills north of the Eagle Mountains, and of the Devil's Ridge, a series of Cretaceous hills and cliffs west of the Eagle Mountains, and the country between these and the Quitman Mountains.

Just after New Year's, having received the long-expected base-bars, I began the measurement of a base line in the flat, six miles west of Torbert, on the north, and 200 feet off from the track of the Southern Pacific Railroad. After training an insufficient number of men (it was impossible to get more help), I laid down a line, which, when corrected for inclination, contraction, and expansion by thermometrical changes, measured 6400.70070 metres.

I set stones at both ends of the base lines. The starting point and end of the line are marked by iron pins in holes bored in the stones and filled with lead. Both these stones, and a third one at a distance of 100 feet west of the east end of the line, are protected by a covering of rocks piled over them.

From this line I began to take triangles to points which I thought of greatest importance for future topographical work, but avoided any attempt to lay triangles of the first order, or of taking any long sides, since the instrument at my disposal (a good field transit, of Gurley's make), is not sufficiently delicate for such work. I took a number of observations up to the time that the setting in of sand and snow storms rendered field work impossible.

The instruments were carefully boxed up, and with other implements were left with the justice of the peace at Sierra Blanca. I then took the animals to Fort Davis, where I turned them loose on the range of Capt. Dolan, mayor of Fort Davis; paid off the drivers, and left with the assistants for headquarters.

W. von STREERUWITZ,
Geologist.

REPORT OF MR. W. F. CUMMINS.

AUSTIN, TEXAS, March 31, 1890.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—Having received instructions to make as detailed a section as the time would permit of the southern part of the Carboniferous formation in Central Texas, I took the field at Lampasas on March 13, with Mr. C. C. McCulloch, Jr., as assistant. The general route was west to the Colorado, then south to the contact of the Carboniferous and Silurian near Cherokee Creek, San Saba County. From that point we traveled north and west to the town of San Saba, and thence, via Richland Springs, Milburn, Trickham, and Waldrip, to Santa Anna. We then turned southwest to Brady, Camp San Saba (McCulloch County), reaching San Angelo May 31. In making the examination the greatest care was taken in the exact identification of strata. Where there was a stratum which could be recognized with certainty, it was traced from hill to hill until its exact relationship to the over and underlying beds was determined. This was prevented by the drift in many places, and therefore a continuous section could not be secured. Wherever an exposure of sufficient extent was found, instrumental measurements were made of dip, etc.

Having completed this, I received instructions to continue westward and make a like investigation of the Permian area. I therefore, with my party, began the work of exploring the Permian formation at its extreme southern limit, which is a few miles south of San Angelo, in Tom Green County. The boundary of the formation had not been definitely determined except at places widely distant from each other along the eastern edge. I therefore undertook to trace the eastern boundary of the beds, or the line of contact between the Coal Measures and the Permian. I traveled down the main Concho River to a point almost south of Ballinger and a few miles above the confluence of the Concho and Colorado rivers. I then went to Ballinger, in Runnels County, and thence by way of Buffalo Gap to Baird. Finding at Baird that I was east of the contact between the two formations, which had been obscured by the overlying Cretaceous to the south, I turned westward to Abilene, in Taylor County.

The line of contact between the Carboniferous and Permian is seven or eight miles east of Abilene. At Abilene I was joined by the State Geologist, who accompanied the party to the Double Mountains. From Abilene we turned northward to the Clear Fork of the Brazos River; we then went down the river northeastward, being all of the time on the beds of the Permian; and passing through old Fort Phantom Hill, we reached the road from

Albany to Haskell. At that locality we found the contact between the two formations. From thence we traveled almost west to the Double Mountains, in the western edge of Stonewall County. From there we went south to Sweetwater, on the line of the Texas and Pacific Railroad, passing through the town of Fisher, sending the balance of the party back to Albany. From Albany we ran a line of levels on a northwest line to Kiowa Peak, in the northeast corner of Stonewall County. From thence we went west to the edge of Kent County. Thence southwestward to the Salt Fork of the Brazos River, and carried the line to the mouth of White River. Thence up that river to the edge of Floyd County.

Mr. N. F. Drake had charge of the topographic work on this trip, and has proven himself quite efficient in his work, the results of which will be published in a later report.

The difference of present altitude above sea level between the lowest and highest beds of the Permian, as determined by this Survey, is 916 feet. This would be on a line from Clear Fork of the Brazos, near the line of Shackelford County, to Dockum, in the western edge of Dickens County.

W. F. CUMMINS,
Geologist.

REPORT OF MR. R. T. HILL.

AUSTIN, TEXAS, March 31, 1890.

Mr. E. T. Dumble, State Geologist:

DEAR SIR—In accordance with your request upon organization of the Survey, I undertook, in February, 1889, in co-operation with my duties as instructor in the University of Texas, the study of the natural features of those portions of the State known as the Black and Grand Prairie regions and the accompanying Upper and Lower Cross Timbers, all of which are the surface features of the Cretaceous rocks, to which they owe their topographic individuality, economic possibilities, and conditions for human habitation.

The work was originally taken up with the hope of bringing the instruction given my classes into closer contact with the practical side of Geology by the utilization of the students in the field and training them for positions upon the Survey; but this was found to be impracticable, and you gave me the assistance of the young men whose names and service are mentioned more fully in the accompanying pages, by whose faithful and painstaking labor much has been accomplished. In the month of July I received an appointment as Assistant Geologist upon the United States Geological Survey,

in co-operation with your Survey, which brought with it a small remuneration for my services, which had previously been entirely voluntary.

The extent and character of the region to be surveyed, as set forth more fully in the accompanying paper, embraced an area of over 72,512 square miles, or over one-fourth (27.75 per cent) of the total area of the State—a region three times as large as the combined area of Massachusetts and Connecticutt, Rhode Island, New Jersey, and Delaware, or three times the size of West Virginia. Since it would have been a physical impossibility for the whole force employed upon your Survey to have covered this enormous area with even a reconnoissance, it became a matter of necessity that the region should be divided into working districts, and the work of my assistants limited to some certain portion.

In accordance with the necessity, the total area was subdivided, therefore, into the following artificial divisions for working convenience:

1. Northern District, or portion north of the Colorado, including 24,000 square miles.

2. Southern District, or portion south of the Colorado, including 48,000 square miles.

3. Isolated areas, including remnantal patches surrounding the buttes of Northwest Texas, or preserved in the mountain disturbances west of the Pecos, or exposed in the Tertiary areas of East Texas by denudation. Area not estimated.

The Northern District was chosen as the best adapted for preliminary operations, and the work has been confined to that field.

Unlike most districts of the State, this region has been thoroughly reconnoitered by previous investigations, and hence it was resolved to make whatsoever work was undertaken of a complete and final character.

GEOGRAPHIC AND TOPOGRAPHIC WORK.

The absence of good geographic and topographic maps has been seriously felt, except in the small portion of the district covered by the United States work, but it has been impossible to devote time to the correction of these deficiencies, although some valuable data has been necessarily collected under this head.

STRATIGRAPHIC WORK.

Since all geologic products of economic value are derived from the rocks composing the strata, considerable work has been devoted to the ascertainment of the stratigraphic conditions of the region, part of which has been of the character of reconnoissance to ascertain and define the sequence of the rock sheets and a part to the making of carefully measured and delineated

cross-sections, for the purpose of showing the inclination, thickness, and sequence of the rock sheets. Much time has also been devoted to the tracing of the boundaries and areal distribution of these different strata upon the surface, and also to office work in mapping and recording the results thus determined.

RECONNOISANCE.

I have made several trips for the purpose of ascertaining the boundaries of my district and locating my assistants upon them. In addition to these, many visits have been made by me to the rocks in the vicinity of Austin for the purpose of ascertaining their sequence and defining their characteristics.

CROSS–SECTION WORK.

Three accurate parallel cross-sections of the region have been commenced and progressed towards completion. These approximately follow the breaks of the Red, the Brazos, and the Colorado rivers, respectively, and are further explained in the report of the work of Mr. Taff, which is appended. These cross-sections have been made with great care and accuracy, and when completed will be of incalculable value in all stratigraphic and common determinations.

The tracing of the areal extent of the formations determined by the cross-sections has been faithfully performed by Messrs. J. A. Taff, C. C. McCulloch, N. F. Drake, and J. S. Stone, as will be seen in their appended reports. Over 2204 miles of partings (boundaries) have been traced and located, fixing permanently the lines of demarcation between the different characters of the country composing the surface of the region. These boundaries are absolutely essential to all geologic questions that can arise concerning the region and are a fundamental and essential portion of the work. The main subdivisions of the district have been accurately located, including the Upper and Lower Cross Timbers, the Grand Prairie, the Black Prairie, and the boundary between the Cretaceous region and the East Texas region on the east, and the Central Texas features on the west.

ECONOMIC INVESTIGATIONS.

The foregoing operations have all been essential and preliminary to a thorough economic investigation of the region. All lines of economic work, however, have progressed hand in hand with these preliminary surveys, as fast as possible, and already results of value are foreshadowed and are being described and recorded as rapidly as accuracy will permit.

ILLUSTRATION.

Several weeks were devoted to the procurement of suitable illustrations of the Cretaceous areas, and for this purpose I have secured through the agency of Mr. C. W. Eddy, the photographer of the Survey, a magnificent suite of negatives, illustrating the characteristic structure, weathering, topography, building material, fossils, and vegetation of the Cretaceous regions. These pictures will be invaluable in illustrating the unique natural conditions of the region.

OFFICE WORK.

I have spent much time upon the necessary work of preparing the results of observations for publication, and in study of material. In order to render the work accurate much library research has been necessary, and this was done in the libraries of the East, during the summer, in ascertaining the work of previous investigators, in order to avoid unnecessary duplication, and in the verification of details. Many pages of manuscript have been prepared, and numerous technical papers published, containing concise preliminary definitions, which must necessarily precede all results of permanent economic value.

Messrs. Taff, McCulloch, and Stone have all been employed for a few weeks each in office work for my division.

WORK OF ASSISTANTS.

Most of the details of the work have been carried out by the able young assistants whom you have placed at my disposal.

Mr. J. A. Taff.—One of these, Mr. J. A. Taff, has been constantly engaged upon the work, he having general charge of the field work. The faithfulness and accuracy of his labors are worthy of special commendation. In addition to his services in the field, he has done valuable work as a draughtsman in the office. He has traced, mostly on foot, over 2000 miles of partings, and accurately located them. In addition, he has made over 200 miles of instrumental cross-sections. A brief summary of his work is as follows:

The Basal Trinity Beds were traced from the Colorado River, at the west line of Travis County, through Burnet, Lampasas, Mills, Brown, Comanche, Erath, Eastland, Hood, Parker, Jack, Wise, Montague, and Cooke counties to Red River, a distance of 400 miles.

A section was made along Red River basin from Nacona, Montague County, through Montague and Cooke to Denison, in Grayson County; length 10 miles. A section was next made across Red River basin, at Gainesville, Cooke County, followed by one across Red River basin at Denison. The

contact between the Eagle Ford shale and the chalk was then determined from four miles south of Denison through Grayson, Collin, Dallas, Ellis, Hill, and McLennan counties to a point on Brazos River one mile below the mouth of Aquilla Creek, McLennan County, a distance of 164 miles. Mr. Taff then took up the location of the Trinity sand contacts and the study of the Cretaceous rocks, west of the main Cretaceous border, in Eastland, Callahan, Taylor, Nolan, Coke, Runnels, and Coleman Counties. Ten miles of basal Cretaceous contact was located in Eastland County, 109 miles in Callahan, 154 miles in Taylor, 234 miles in Nolan, 68 miles in Coke, 39 miles in Runnels, and 80 miles in Coleman County. This was followed by construction of a section from base of Trinity sands, 10 miles west of Dublin, across Erath and Bosque counties, to Walnut, Bosque County, a distance of 40 miles. The following sections were then made:

1. From Dallas across Dallas, Tarrant, and Denton counties to Decatur, Wise County, a distance of 60 miles.

2. Across Bosque River basin at Alexander, Erath County, and at Iredell, Bosque County.

3. Down the Colorado River basin from the mouth of Hamilton Creek, Burnet County, across Burnet and Travis counties, to Austin—32 miles (in this latter section he was assisted by Mr. Drake). In company with Mr. Stone, the Cretaceous and Tertiary contact was then traced from Webberville, Travis County, across Travis, Williamson, Milam, Falls, Limestone, Navarro, Henderson, and Kaufman counties to three miles east of Terrell.

Mr. N. F. Drake.—Mr. Drake also performed faithful service in the field during the months of July, August, and September, tracing out the boundaries between the various regions, as shown below.

The Upper Trinity sand contact was traced from Decatur, Wise County, southward across Wise, Parker, and Hood counties to Acton, Hood County—90 miles.

The boundary of the Exogyra Arietina clay located from Brazos River at Bosqueville, McLennan County, across McLennan, Bell, Williamson, and Travis counties to Austin—125 miles.

The Basal Austin Chalk contact was traced from the Brazos River, at mouth of Bosque River, across McLennan, Bell, Williamson, and Travis counties to Austin—125 miles; and the Austin Chalk Ponderosa Marl contact from Austin to twenty miles into Williamson county. Mr. Drake was then transferred to work under Prof. W. F. Cummins.

Mr. C. C. McCulloch spent the months of May and June in the field and did the following work:

Upper Trinity contact was traced northward from Decatur, Wise County,

across Wise, Montague, and Cooke counties, to Red River, north of Marysville—70 miles.

The basal contact of Lower Cross Timber sand was then traced from Red River, north of Gainesville, Cooke County, across Cooke, Denton, Tarrant, Hill, and Johnson counties to Brazos River at west line of McLennan County—175 miles.

The Upper contact of Lower Cross Timber sand was determined from Red River, near Gordonville, across Grayson, Denton, Tarrant, Dallas, Johnson, Hill, and McLennan counties to Ross, McLennan County—175 miles.

In addition, Mr. McCulloch's services have been employed in delicate paleontologic determinations and editorial work for my division. His services have been of great value in many important branches.

Mr. J. S. Stone relieved Mr. Drake in November, and was placed with Mr. Taff upon the eastern line of the region. His training in surface geology has been of great service to the work.

R. T. HILL,
Geologist.

REPORT OF MR. THEO. B. COMSTOCK.

AUSTIN, TEXAS, March 31, 1890.

Mr. E. T. Dumble, State Geologist, Austin, Texas:

SIR—In accordance with my original engagement with you, I reported for duty at Austin, June 20, 1889, and started next day for Burnet, with Charles Huppertz and C. H. Shamel as aids, under your instructions to make a rapid review of the Central Mineral Region for the purpose of outlining a plan of survey. Employing Richard Maxwell, of Bluffton, as cook and teamster, I spent sixteen days (owing to delays by floods in the rivers) in traveling through parts of Burnet, Llano, Mason, Gillespie, and Blanco counties. Upon my return to Austin, plans were matured for the complete survey of the district, which, it was then supposed, would comprise about the area of three full counties. Your instructions gave me "the charge of the study of all the territory within the Central Paleozoic Area, from the earliest rocks to the base of the Carboniferous System, with such further work in other terranes as may be necessary in your judgment to a clear understanding of the structure of the district." It was thought that this limited field could be covered fairly in the three months for which I had been engaged, and at the expiration of that period, in September, enough work had been done to enable a report to be prepared embodying all that was originally contemplated, although

at that date we had ascertained that a large outside area of what had previously been regarded as Carboniferous territory is really of earlier age. Arrangements were therefore made by which I became permanently attached to the Survey as the Geologist for Central Texas, and the accompanying report is transmitted as a preliminary statement of the work performed up to the date of going to press with your Annual Report for 1889.

From June 23, 1889, until September 15, 1889, the personnel of this division of the Survey was as below:

Theo. B. Comstock, geologist in charge.

James C. Nagle, topographer.

Charles Huppertz, geological aid.

David W. Spence, aid.

Oran G. Bunsen, rodman.

Harry Spence, rodman (July 25 to September 25, 1889).

R. V. Sanders, cook.

Richard Maxwell, hostler.

No important changes were made after the renewal of work in September, except that Mr. David Spence left at that time, and the funds were insufficient to enable me to supply his place. Mr. Bunsen, however, was partly employed as general aid, in addition to his duties as rodman. Mr. O. W. Wilcox replaced Harry Spence as rodman late in September, and J. L. Nichols was engaged from late in October until December 5 as cook, in place of R. V. Sanders. Mr. Nagle assumed temporary charge of the field party during my absence in September, so that there was practically no cessation of the work from June to December.

Upon the return from the field, December 6, the field party was disbanded. Mr. Nagle was retained to work up the topographical notes and sketches, and he has prepared maps with fifty feet contour intervals, upon a scale of 1040 feet to one inch, which he has reduced upon one sheet to the scale of $\frac{1}{125000}$ (about two miles to the inch). This is not yet ready for publication, owing to gaps which remain to be filled. The data for its construction were obtained by transit and stadia work with the solar compass, along lines daily selected by myself with reference to both geologic and topographic needs of our Survey. These lines comprise about 500 miles of geologic sections, the adjacent topography being accurately taken, and the intervening areas being omitted, except where some check could be made upon the work. The triangulation of the United States Geological Survey, under Major Powell, affords us a very satisfactory basis, but the sketched topography in the published maps has been found unreliable, in large measure, owing, it would seem, to rapid work, and to undue dependence upon odometer and aneroid measurements. Some very convincing tests, made by us last season, have

satisfied me that none of the rough methods of survey which are applicable in regions where the geology is simple can be successfully utilized in a region of such complicated structure as this. Mr. Bunsen was also employed as general assistant in the laboratory. Mr. Huppertz has been sent out at different times during the winter to make special investigations, such as are credited to him in the report.

I desire to express my gratification at the uniform courtesy and energy at all times displayed by every one of my assistants. The zeal and endurance exhibited by each member of this division have had very much more to do with such merit as the report may possess than it is possible to express here.

Thanks are also due to the large number of citizens in the district who have aided us freely in ways too numerous to recite. The interest manifested by them, and the good will always expressed and practically shown, have added new incentive to the heavy tasks set us in a region much confused, geologically.

There remains much to be done to make our work complete, although the accompanying report does not contain the largest part of the illustrative material which has been collected, nor will all the conclusions which are warranted be fully understood without much more study in the laboratory than has yet been feasible. Much of the work already done in this way is merely outlined in this preliminary report, but we are in much better shape for attacking the remaining problems by reason of the foundation laid by this outline.

Under your instructions, plans have been made for the work of 1890, and it seems probable that we may be able to settle most of the doubtful points before the next Annual Report is issued.

The idea most prominent in the investigations has been always to gain such a knowledge of the material resources of the country as will give practical men the means of forming a judgment of their value and capabilities of development. Wherein there is a deficiency in this respect in the report I feel that I may safely claim that it is due to the absolute necessity of first getting a clear understanding of the geologic structure as a basis for calculation.

In conclusion, let me add that your own constant encouragement and sympathy, and the freedom of action granted to me, as well as the invaluable counsel given by you, have been by far the greatest aids in my work, and that to these in large degree must be attributed what may, perhaps, without undue arrogance, be regarded as the success of our labors the past year.

With high esteem, very respectfully,

THEO. B. COMSTOCK,
Geologist for Central Texas.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY.

PAPERS ACCOMPANYING THE ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY OF TEXAS

FOR

1889

A
PRELIMINARY REPORT
ON THE
GEOLOGY OF THE GULF TERTIARY OF TEXAS
FROM
RED RIVER TO THE RIO GRANDE.

BY

R. A. F. PENROSE, Jr.

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INTRODUCTION.

The literature on the subject of the Geology of East Texas is very fragmentary and vague. This might well be said of all parts of the State, yet it is especially true of the eastern part.

The first systematic work of a geological nature done in East Texas, was by Dr. Ferdinand Roemer, who visited Texas in 1845–47; but even he, as also most succeeding investigators, quickly moved into the Cretaceous and Paleozoic regions lying in the western part of the State. He published two principal works, both in German, entitled:

1. "Texas, with Special Reference to German Emigration," etc., with a topographic and geognostic map of Texas. Bonn, 1849.

2. "The Cretaceous Formations of Texas and their Organic Remains, with a Description of the Accompanying Paleozoic and Tertiary Strata." Bonn, 1852. Besides these works, Dr. Roemer also published several articles on Texas, in the American Journal of Science and Arts.

The Report of the Mexican Boundary Survey, of 1848–1855, contains data on the geology of the region, by Arthur Schott; also, papers by James Hall and T. A. Conrad, who, though they did not accompany the Expedition, drew conclusions from the specimens collected. These statements, however, relate only to the region in the immediate vicinity of the Rio Grande, and not to East Texas proper.

The printed reports of the State Geologists, 1858 to 1876—Dr. B. F. Shumard, Francis Moore, S. B. Buckley, and John W. Glenn—contain but little information concerning the eastern part of the State, although some of the iron localities are described, and sections given.

In 1884 Professor Angelo Heilprin published his work entitled "Contributions to the Tertiary Geology and Paleontology of the United States." This

volume comprises all of the little that was then known regarding the geology of the Tertiary area of East Texas.

Professor E. D. Cope, of Philadelphia, has published accounts of the fossil vertebrates of Central and Eastern Texas,* and has added greatly to our knowledge of the subject in those regions.

In 1884 R. H. Loughridge published in the "Report on the Cotton Production of the State of Texas, with a Discussion of the General Agricultural Features of the State," Tenth Census of the United States, Vol. V, 1884, pp. 653–831, a brief account of the Geology of Texas, and a much more detailed account of the soils and the agriculture. It gives a great deal of valuable data, collected over a large area, but mostly in Central and West Texas.

In 1888 there appeared, as a congressional document, a report on "The Iron Regions of Northern Louisiana and Eastern Texas," by Lawrence C. Johnson, Assistant Geologist United States Geological Survey. This outlines the iron ore area of Louisiana and Texas, and gives data respecting the geological formations of those sections.

In the Report of Progress, for 1888, of Mr. E. T. Dumble, State Geologist, there is a short account of the iron ores of East Texas, by R. A. F. Penrose, Jr.

Here ends the list of geological literature on East Texas. Though many works on Central and Western Texas have been published, it is not necessary to mention them here, as they do not refer to the question under consideration, and have been already summarized by Mr. R. T. Hill.†

It will be seen that what little is known of East Texas consists largely of fragmentary and vague statements, made often in connection with and as subordinate to other interests. It is purposed in this preliminary report to make as concise a statement as possible of the facts already noted, not only in East Texas proper, i. e., the country east of the Brazos, but also at various points on the Colorado River and Rio Grande. The various data will be described under two principal headings—Descriptive Geology, and Economic Geology.

In conclusion, I wish to express most sincere thanks to Professor Angelo Heilprin, of the Academy of Natural Sciences, Philadelphia, for much valuable advice and information. I also wish to express the same thanks to Professor R. T. Hill, of the University of Texas, for his kindly assistance and advice during the prosecution of the work.

* Bulletin of the United States National Museum, No. 17, "On the Zoological Position of Texas," 1880, and elsewhere.

† R. T. Hill: "The Present Condition of Knowledge of the Geology of Texas." Bulletin of U. S. G. S., No. 45, 1887.

DESCRIPTIVE GEOLOGY.

GEOGRAPHY AND TOPOGRAPHY.

The name East Texas is generally applied to that part of the State lying east of the Brazos River. This area is bounded on the north by Indian Territory and Arkansas, on the east by Louisiana, on the south by the Gulf of Mexico, and on the west by the great prairie region of Central Texas. A large part of this area is a heavily timbered region, and marks the southwestern terminus of the great Atlantic timber belt, extending from the Arctic regions continuously along the coast of the Atlantic Ocean and the Gulf of Mexico, until it finally disappears in the mesquite and cactus prairies between the Colorado River and the Rio Grande.

The country consists largely of the in-shore part of the bottom of the old Tertiary Sea, which once covered the whole Gulf coast. This area has been elevated into a table land one hundred to seven hundred feet above the present sea level, sloping gradually to the southeast, and emptying its waters in the same direction into the Gulf of Mexico. Since its elevation it has undergone great erosion, and is still being denuded at a tremendous rate. The strata are all composed of sands and clays, and succumb very readily to the eroding action of the atmospheric agencies. The result is that all that is left of the once level surface of this table land are a few flat-topped hills and ridges, such as are seen in the northeastern counties. East Texas as thus defined comprises a coast prairie region on the south, a great timber region in the center, and an interior prairie country in the north and northwest. The coast prairies reach inland along the Sabine about fifty miles, but as we go west they spread farther and farther towards the interior, until, when we come to the Brazos, they reach up the river for over a hundred miles. Near the Gulf shore they are flat and low, rising twenty to thirty feet above tide water, thickly covered with grass and cut by steep-sided channels of many rivers and creeks. The monotony of the scenery is broken only by the narrow strips of timber which follow the meandering courses of the streams down towards the Gulf of Mexico. As we go inland the country slowly rises, and though the prairies in their easterly part maintain their flat character, to the west they become more undulating and broken, and groves of mesquite, hackberry, cottonwood, and other trees are seen in many places. Finally, we come to the beautiful rolling country of Washington and Grimes counties, the southern border of the timber region. Continuing west across the Brazos, the prairies rapidly encroach more and more on the timber of the interior, until they cut

it out altogether, and finally blend, beyond the Colorado, with the great prairies of Southwest Texas. The timber that is found in the coast prairie region of East Texas, along the streams and in isolated groves, is mostly cottonwood, willow, elm, hackberry, sycamore, ash, water oak, pin oak, post oak, some red oak, and cedar, and, in the western part of the area, pecan and mesquite. Dense growths of vines, rattan, poison oak, and grape vine, have often wrapped themselves about the trees, forming an impassable network. The spread of the mesquite in this region is a noteworthy fact. When the country was first settled it was a rare tree in the valley of the lower Brazos, and was identified only with the western prairies. Since that time, however, it has spread to the east, and is now seen in considerable quantities about Sealy and other Brazos River towns. As we leave the coast prairies and enter the timber, we come into a much higher, more rolling, and broken country, heavily covered with pine, oak, and hickory. This is the region of gray sandy soils on the highlands, red clay or loamy soils on the lowlands, and rich dark chocolate soils in the river bottoms. The country varies from two hundred to six hundred feet above the Gulf, and sometimes, though rarely, the hill tops approach even seven hundred feet. These hills have all been formed by the erosion of the surrounding country, and nowhere in East Texas are there found any elevations which have resulted from the disturbance or contortion of the strata. The highest points in the timber region, like Mount Selman and Gent Mountain, in Cherokee County, Hynson's Mountain, in Harrison County, and many others, have their summits capped by a horizontal, or almost horizontal, bed of iron ore or sandstone, and to this covering they owe their existence, it having protected them from the erosion which has worn down the surrounding country. It has also given rise to a striking topography very much like that of the western lava plains on a small scale. The hills, locally called "mountains," sometimes occur as small, flat-topped hills—the "butte" and "mesa" of the west—and at others spread out in broad plateaus, sometimes covering an area of twenty or thirty square miles, deeply cut by the steep sided canyons, and often showing an almost perpendicular slope. Such regions afford a beautiful upland country, with a soil far different from the surrounding lowlands, and a climate excellently adapted to the cultivation of fruit. In fact, such lands are now among the greatest fruit districts of Texas, and bid fair to become a worthy competitor of the California fruit country. Gent Mountain, in the western part of Cherokee County, is a beautiful example of this plateau country. It comprises over twenty square miles of area, is largely underlaid by iron ore, capped by a sandy soil, and thickly covered with oak and hickory. From its summit, looking south and west, can be seen the lowlands of the Neches River bottom, and beyond, the rolling country of Anderson County. To the north can be seen Gray's Mountain, Grimes Mountain, Rags-

dale Mountain, and many other iron clad hills. To the east looms up a similar range, constituting the iron ore plateau of Rusk and New Birmingham. The timber of this region differs considerably in different parts. In the southeastern corner, between the Sabine and the Trinity rivers, is the long leaf pine region. It extends from the northern edge of the coast prairies inland for over a hundred miles, and finally gives way to the short leaf or yellow pine, the oak, and the hickory. To the west of the Trinity it also becomes more and more scattered, giving place to the loblolly pine, until it disappears altogether. This area is the terminus of the long leaf pine belt, which extends continuously from the Carolinas through Georgia, Florida, Alabama, Mississippi, and Louisiana.

To the north and northwest of this region we come into a country covered mostly by short leaf pine, post oak, blackjack, and hickory, with smaller quantities of sweet gum, ash, white oak, black oak, pin oak, water oak, walnut, willow, cottonwood, sycamore, and in still smaller quantities black gum, maple, black locust, cedar, thorn, holly, black hickory, shell-bark hickory, mulberry, birch, sassafras, and cypress. In the Trinity River bottom and to the west of it large quantities of pecan are found, but to the east of that river it is entirely wanting. Grape vines are of universal occurrence, and occasionally rattan is found. The timber in many parts of this region is very dense, and in places is on the constant increase. It was in 1840 to 1850 that the timber region of Northeast Texas began to attract attention and immigration began. Stephen Austin, as early as 1821, had led a party of Americans to the banks of the Brazos and there, on the land originally granted by the Mexican government to his father Moses Austin for a colony, founded the first American settlement of importance in this region. But this was in the coast prairie country, and it was twenty years or more later that the country to the north began to attract the pioneer. At that time the timber of the region was scattered, and the only places where dense vegetation was seen were in the river bottoms and along the bayous, creeks, and lowlands, where many kinds of oak, walnut, gum, and, in places, cypress flourished in all the virgin luxuriance of a comparatively warm, moist climate. On the uplands, and especially in the great sandy plateau regions, the ground was covered by a luxuriant growth of tall grass, and the timber was scattered and confined to large oaks and hickories, which offered no obstruction to the free passage of wagons and stock. In fact, travel through it was as easy as on the open prairie. But with the appearance of the white man and the withdrawal of the Indian came a great increase in the density of timber, especially oak, hickory, ash, etc., and it may safely be said that in spite of the large amount of land which is now cleared and under cultivation, the quantity of hardwood timber in Northeast Texas is to-day greater than when the plough of the white man first broke the soil half

a century ago. The present growth of timber on the plateau country is not so large as that which originally covered it, but it is very dense, and in many places is a great hinderance to travel. Numerous explanations have been given for this increase of timber, but the one which is popularly accepted, and for which there is most proof, is as follows: The Indians were accustomed every autumn to burn the tall grass, which at that time became very dry and combustible. This had the effect of killing off any small shoots and saplings which had grown up during the previous year, and though it did not injure the large timber it kept it from increasing in quantity. The object of the Indians in doing this was doubtless to drive the game into certain parts of the country; or else, knowing the tendency of the timber to grow up into a dense forest, the object was to keep it down and thus facilitate his hunt.

Professor N. S. Shaler,* speaking of this matter, says:

"These annual forest fires were kindled either to drive the game towards the hunters or to aid the growth of the fresh grass which springs up after the conflagration. In this way the prairies were extended eastward to Indiana, and south to the Ohio River. At a point west of Louisville, Kentucky, the prairie crossed that stream and extended south to the Cumberland River, near where Nashville now lies. In this latter region we have a clear example of the process by which the country was deforested. When the whites first came to the Ohio Valley this prairie region between the Ohio and the Cumberland rivers occupied the whole belt of limestone land of Western Kentucky. Skirting the southern border of the western coal field, it extended westward across the Cumberland and Tennessee rivers into the low table-land which lies between the last named stream and the Mississippi River. About five thousand square miles of this area were actually deforested, except where, beside the scanty streams, the ground was too moist to permit the ravages of the annual conflagrations. On the border of this area the old trees were not destroyed, but remained in the form of a very open forest. The younger growth was, however, wanting. The reason for this is plain: The older trees have a very thick outer bark, which served to protect them from the damage which would be inflicted by the momentary heat of the burning leaves, while the tender stems of the saplings were easily destroyed. Thus it came about that when the old trees died they left no successors, and so the prairie steadily widened its area.

"As soon as the Indians ceased to use Kentucky as an annual hunting ground the forests rapidly regained their possession of all the prairie lands of this district. The annual burning of the surface ceased in the latter part of the last century; in the second decade of this, the whole of this great area was covered by a thin wood of young trees, which quickly closed into a dense forest. At the present time all the parts of this field which have not been deforested by man are thickly wooded. Some indications of a similar process of forest restoration may be found in Indiana and Illinois; but in those regions the annual rainfall is less, and summer droughts, which are calculated to prevent the establishment of the young trees, are more frequent and more prolonged than in Kentucky."

The same phenomenon occurs in Arkansas, and the local explanation is the same as that given above. Of course local causes may have entered into the problem. The breaking of the sod by the plough and by rooting of hogs,

*N. S. Shaler, "Aspects of the Earth," p. 287, New York, 1889.

which are allowed to run loose in the woods, may have been important factors in offering opportunities for acorns, etc., to take root. As we approach the western border of the timber belt the short leaf pine disappears altogether, and the forests are composed of the other woods mentioned above, especially post oak, blackjack, hickory, and ash. As we continue north and northwest through the timber belt, we again emerge into an undulating prairie country, which extends thence into Central and West Texas. The soil is a very fertile black clay, and cottonwood follows the courses of the streams until they finally disappear in the forests to the east. East Texas is well watered, not only by rivers and creeks, but by numerous springs and a rainfall which, though not confined to any special part of the year, is most plentiful from December until April. Unlike the country to the west, it rarely suffers from severe drought. Lakes are of very rare occurrence, and are never seen except in river bottoms, where they form muddy lagoons, abounding in fish and generally fed by springs. They are often of considerable depth, and are connected with the main river by narrow channels. The only instance of an upland lake seen by the writer in East Texas is in Freestone County, some five miles west of the Trinity River, and amounts to little more than a large spring. It is a small circular body of clear water, occupying a depression in the clayey strata, some two hundred yards in diameter, and fed by springs. It empties into the Trinity River and occupies an elevation of 175 feet above it. The absence of lakes in this country is due to two causes:

1. The porous nature of the sandy strata which underlie the country and which form the ready channel for the subterranean drainage of a possible lake basin.
2. The softness of the strata, which renders the natural cutting of channels a very rapid process, and consequently makes the existence of a closed basin suitable for a lake almost impossible.

In spite of the low elevation of many parts of East Texas, swamps are rare, and in most places entirely unknown. The few that do exist are found along the rivers and in the coast bayous, near their mouths, especially in the lower part of the Sabine and thence towards the Trinity.

The main rivers of East Texas are the southwesterly (coastward) continuation of the great rivers of the prairie country. They all preserve a general easterly or southeasterly course, and in the low coast prairie country, as they reach base level, become very crooked and meandering. In the rivers of Texas there is no well defined "fall line," as described by McGee* and others in the Atlantic States. The rivers are often very swift in their upper courses, and become more and more sluggish as they enter the timber and approach

* "Three Formations of the Middle Atlantic Slope," W. J. McGee, American Journal of Science, Vol. XXXV, p. 120, February, 1888.

the Gulf, but the transition is gradual, and it is impossible at any place to draw a sharp division that might represent the "falls line," or line of separation of the highland and lowland. These rivers rise in various parts of the State, and hence the sediments which the comparatively swift waters of their upper courses carry down and deposit in the quieter basins in East Texas vary considerably in character. The Red, Brazos, and Colorado rivers rise in the eastern slopes of the Staked Plains, in Northern Texas, pass through the Red (gypsiferous) Beds, the Paleozoic rocks, and the great Cretaceous area of Central Texas, and finally deposit in East Texas a sediment composed of materials from these regions, in the form of a highly calcareous red silt. The Trinity rises in the Carboniferous rocks of Northern Texas, but far east of the Staked Plains, and passing down through the Cretaceous prairies, becomes charged with calcareous matter. Hence its sediments, though often calcareous, do not have the red color of the Red, Brazos, and Colorado rivers. The Sabine rises still east of the Trinity, while the smaller rivers, such as the Neches and Angelina, rise in the timber region, and the character of the sediments of them all varies with the region they rise in and flow through.

Though terraces of gravel and river silt are found along the rivers, and sometimes reach down to the water edge, yet all of them may be said to flow in channels cut in the older sediments, as such strata crop out at very frequent intervals along their courses. In this respect they resemble the Mississippi, in connection with which a similar statement has been made by Humphreys and Abbot*.

Loughridge† gives the following drainage areas for some of the East Texas rivers:

The Sabine River, on the Texas side, drains...........17,100 square miles.
The Trinity River drains......... ....16,600 square miles.
The Brazos River drains ....35,000 square miles.

The Brazos has a greater drainage area than any other Texas river. It receives many tributaries in its upper part, but below the basin is narrow, and small streams instead of emptying into it run direct to the Gulf. All of the Texas rivers are navigable to a greater or less extent, and until the introduction of railroads an extensive shipping business was carried on in transporting the cotton production of the region. Of course the amount of freight that could be carried depended on the high or low condition of the water. Now, however, boats rarely go up them for any considerable distance, as the journey

* "Report on the Physics and Hydraulics of the Mississippi River," by Captain A. A. Humphreys and Lieutenant H. L. Abbot, 1861.

† R. H. Loughridge's "Report on the Cotton Production of the State of Texas, with a Discussion of the General Agricultural Features of the State." Tenth Census of the United States, Vol. V, 1884, pp. 653–831.

takes a long time on account of the currents in the rivers, and, consequently, competition with railroads is impossible. The Sabine was formerly navigated for three hundred miles from its mouth, while cotton boats capable of carrying a thousand bales made regular trips up the Trinity to Green's Landing, in the northwestern part of Anderson County. A small steam launch is also said to have once ascended this river as far as Dallas. The Brazos was navigated before the railroads came in up as far as the town of Washington, and boats are said to have gone up even to Marlin Falls, a distance of six hundred miles. The Colorado River has only been navigated in places. A small steamer carrying cord wood once plied a portion of the river in the neighborhood of Austin. A "raft" of drift timber at its outlet prevents the entrance of boats, and therefore prohibits any extensive shipping.

The smaller streams, such as the Neches and Angelina, are navigable for short distances above their mouths.*

STRATIGRAPHY.

East Texas proper, i. e., the region east of the Brazos, is underlaid mostly by Tertiary strata, though to the northwest we come to Cretaceous beds, and on the coast we meet Post-Tertiary clays. The line separating the Tertiary and Cretaceous strata has not yet been accurately run, but points along it have been determined and are sufficient to allow a general line to be drawn. This line runs in a general southwest and northeast direction, crosses the Red River west of Texarkana; thence proceeding southwest it interects the Texas and Pacific Railroad near Elmo, nine miles west of Wills Point, and the Missouri, Kansas and Texas between Corsicana and the Trinity River; it crosses the Brazos in the northeast corner of Milam County; the Colorado ten miles below Austin. Between here and the Rio Grande the boundary line has not yet been run, but the first true Tertiary fossils found on that river, going down stream from Eagle Pass, are met in the northwest corner of Webb County and three miles below the Maverick County line, at a distance almost half way between Eagle Pass and Laredo. The uppermost part of the Cretaceous and the base of the Tertiary strata are both composed of soft clay and sand beds, which succumb readily to the weathering action of the atmosphere, and consequently the line of separation is often impossible to locate exactly. The uppermost beds of the Cretaceous in Texas and Arkansas are composed of sandy and "glauconiferous" strata, sometimes reaching a maximum thickness of three hundred feet. These have been termed the "glauconitic" division by Hill.† They vary in composition from beds of pure siliceous sand to beds

* On the Rio Grande a steamer makes regular trips between Brownsville and Roma, and tradition says that government supplies were once taken up as high as Laredo.

† American Journal of Science, Vol. XXXVIII, December, 1889.

composed entirely of glauconite, and between these two extremes are found all gradations in the relative proportions of the two materials. These beds are the equivalent of the Ripley Division of Alabama, and probably are the Southern representative of the "Fox Hills" beds of Nebraska. The "glauconitic" deposit becomes more argillaceous towards its base, and gradually runs into a great deposit of calcareous clay over twelve hundred feet thick and characterized by large quantities of *Exogyra ponderosa*. This bed represents the "Exogyra Ponderosa Marls" of Hill's Upper Cretaceous section, and underlies a large part of the great prairie region of Central Texas. These Upper Cretaceous beds dip gently at three to five degrees to the south and southeast, and formed the Texas shore line of the early Tertiary sea. Upon their much eroded surfaces were deposited the Eocene clay and sandy strata which underlie East Texas. The "glauconitic" beds have in fact been so much denuded that they now play only an insignificant part in the stratigraphy of that part of the Southwest included in Texas and Arkansas. They are developed in Southwestern Arkansas near Arkadelphia, on the Ouachita, and near the town of Washington,* but to the southwest of the Red River they are, so far as is yet known, almost entirely wanting until we get to Anderson County. Here, some six miles east of the Trinity River and over two hundred miles south of the Arkansas outcrops, is found a small calcareous hill, which is the equivalent of the "glauconitic" beds of the Ouachita. This outcrop covers less than two hundred acres of territory and is surrounded and partly covered by clays of Lower Tertiary epoch. It lies over fifty miles east of the main Cretaceous area of Central Texas, and is in fact a Cretaceous inlier, which doubtless formed an island in the old Tertiary sea. Similar areas have been described by Hilgard† as occurring in Louisiana, where they crop through the Tertiary strata near Chicotville, Winfield, and Salines, and form a range of outcrops running north northwest and south southeast. Going southwest along the old Cretaceous shore line we again find the "glauconitic" strata well developed on the Rio Grande, both above and below Eagle Pass. How far these can be traced to the northeast is as yet uncertain, as the stratigraphy of that region is but very little known. But they doubtless end somewhere between the Rio Grande and the San Antonio River, as they are not found in the latter locality. Consequently it will be seen that the three hundred feet of "glauconitic" strata have, in East Texas at least, been almost entirely eroded, and the underlying "Ponderosa Marls" now form almost everywhere in this portion of the State the uppermost Cretaceous division. Even this bed has been much eroded in many places, and while

*R. T. Hill, Geological Survey of Arkansas, Vol. II, 1889.

†E. W. Hilgard, "Supplementary and Final Report of a Geological Reconnoisance of the State of Louisiana," 1873, p. 43.

in Northern Texas the distance across its outcrop is over thirty miles, east of Austin the distance is less than fifteen miles; yet in both localities the dip is about the same. Of course these differences in the thickness of the bed may be partly due to a lesser deposition of the "Ponderosa Marls" in the latitude of Austin than in the northern part of the State, or else to the greater overlapping of the Tertiary strata, yet the character of the country is such as to prove that a great amount of erosion has taken place. The Tertiary deposits of East Texas, overlying these Cretaceous strata, consist of a vast thickness of sand, clay, and glauconite beds, in some places characterized by great quantities of lignite, and in others by beds of littoral fossils. In fact the whole series represents a succession of coastal, subcoastal, or brackish water* deposits, alternating with marine deposits of a littoral character, and between these two extremes we find all gradations. The lagoon or subcoastal deposits compose by far the greater part of the series, and the marine strata represent slight and temporary submergences of the coastal area. The proofs of the littoral character of the marine deposits are many, and may be summed up as follows:

1. The fossils all represent a littoral marine fauna.
2. Fragments of lignite are frequently found in the marine beds. These must have come from the destruction of a lignite bed on the shore, and have been carried into the sea by rivers tributary to it. They must have been deposited near the shore, as such soft fragments would have been rapidly broken up before they got far out to sea. A bed of this kind is seen at "Bombshell Bluff" on the Colorado River, where numerous fragments of lignite are mixed in with glauconitic beds containing many marine fossils.
3. Frequently lumps of clay or sandy clay are embedded in strata bearing marine shells. These must have been deposited near the coast line, as they could not have stood long transportation without disintegration. A remarkable instance of this is seen in a bluff on the Brazos River at the crossing of the International and Great Northern Railroad, where there occurs a bed of glauconite underlaid by lignitic clays. Fragments of this clay, one to twelve inches in diameter, are found in various parts of the overlying bed.
4. The marine beds are not always continuous, but blend laterally into beds of brackish or fresh water origin. Glauconitic beds containing fossils in one place are often represented in another by beds of pure siliceous sand or by clays containing large amounts of vegetable matter. Such an effect

*This same effect might also be brought about in salt water bays and estuaries into which the rivers from the inland flowed.

could be produced by the evident estuary character of many of these beds.

5. The fossil remains are frequently much broken, worn, and rounded, as if by continued rolling on or near a sea beach.
6. Frequently the fossils are found in great beds of solid shells, sometimes as much as ten feet thick, a condition of things that strongly denotes littoral conditions, and that is seen going on along our coast at the present day. Such beds of fossils are seen on the Rio Grande in many places between Laredo and Brownsville.

The Tertiary strata strike in a general northeast and southwest direction, approximately coincident with the coast, and dip gently toward the east or southeast at an angle varying from 0 to 5 degrees. This dip, however, is very irregular and undulating, and no estimates of thickness of strata based on it can be relied on. In fact, a northerly or northeasterly dip is of no uncommon occurrence, though it is simply a local phenomenon. On the Rio Grande the strata all dip normally to the east and southeast, until we get to a point ten miles above San Ygnacio, when the dip changes to northeast at an angle of 1 to 8 degrees, and retains this direction for a distance of twenty-one miles down the river. Similar occurrences are seen elsewhere, though in no other place were the strata observed to maintain this dip for so great a distance. Usually a northerly dip returns to its normal direction in a distance of a few hundred yards at the most, though a horizontal and undulating dip often extends for many miles. This variable character of the dip, however, does not require the supposition of a disturbance or upheaval of the strata for its explanation. It is doubtless due to the natural sinking and warping in a great thickness of soft beds. In fact, it would seem a most unnatural thing to see several hundred feet of soft clays and sands, covering an area of many thousand square miles, lie horizontally when they were exposed to the influence of atmospheric agencies. The unequal expansion and contraction of strata of different constituents, due not only to heat but to the drying out of the beds, would alone account for much or all of the warping that is exhibited throughout the Tertiary country. Besides, the chemical action that has gone on in these beds is probably also accountable for a part of the variable dip. Faults are of frequent occurrence, and are to be accounted for on the same principle as the variations of dip. They are rarely over eight or ten feet in throw, and play no important part in the features of the country. One of the most clearly defined faults seen is represented in figure 2. Jointing is also a very common phenomenon throughout the whole of the East Texas region.

Estimations of thickness of the Tertiary strata of this region are attended by peculiar difficulties, as the dip is too variable to be relied on in such esti-

mations. The strata are rarely exposed in such a way as to show any considerable thickness of any beds, and reliable records of well-borings are very scarce. It seems possible, also, that much of the Tertiary area may have grown by a gradual encroachment of the land on the sea by a process of accretion, such as is seen in many places on the Atlantic coast to-day, and that it does not always require the supposition of a submergence.*

For the sake of convenience in description, the Tertiary strata underlying East Texas have been divided as follows:

SECTION OF THE GULF TERTIARY OF TEXAS.

LATER TERTIARY? (*Grand Gulf*, Hilgard):	Fayette Beds.	Sands, clays, and lignites.	300 to 400 feet.
	Timber Belt or Sabine River Beds.	Sands, clays, lignites, and glauconites, or green-sand marls.	800 to 1000 feet.
EOCENE:	Basal, or Wills Point, Clays.		250 to 300 feet.

Sufficient data have not as yet been collected to warrant an attempt at a detailed correlation of all the Texas Tertiary with that of the other Gulf States, and therefore the various strata are provisionally divided as above. The classification depends, first on their lithological character; and secondly, on the very different and very characteristic topography that each of the three divisions gives to the country underlaid by it. The Basal or Wills Point Clays underlie a narrow strip of rich rolling prairie region, east of and parallel to the great Cretaceous prairie of Central Texas. The Timber Belt sands and clays underlie the great timber region of East Texas, and the Fayette Beds, so called from their extensive development in Fayette County, on the bluffs of the Colorado River, underlie the interior part of the coast prairies. The coastal part of this latter region is occupied by Quaternary deposits, to be treated later. Throughout the whole of the Eocene area no evidence of any considerable break in deposition can be seen. The lagoon and marine deposits appear to have alternated with each other in an unbroken series. Frequently there are found in one bed fragments of the stratum that underlies it, but no great amount of erosion of these lower beds appears to have taken place, and the little that has gone on is simply what might have been expected to accompany a gradual transition from one kind of deposition to another. The paleontological evidence on this point, though as yet somewhat meagre, all tends to show a gradual and almost continuous deposition from bottom to top of the series, and the few breaks in the fauna that have been observed can probably all be explained by the interposition between the fossiliferous beds of the lignitic and other non-marine strata. In this continuity

*The estimates of thickness given below are simply approximations, and are intended more to show the relative size of the different divisions, than to represent absolute thickness.

of deposition the Texas Eocene closely resembles that of Mississippi, the different stages of which, according to Hilgard,* "are intimately interconnected by community of species, from Claiborne to Vicksburg."

The Texas Eocene contains many Claiborne and Jackson species, but the Vicksburg, so far as is yet known, is but very sparingly represented, as but three or four characteristic forms of that epoch were found among many fossils collected on the Brazos and Colorado rivers in the region where the Vicksburg strata might have been expected to occur. This is in accordance with the observations of Hilgard at Sabinetown, Texas, concerning which he says: "At the base of the Grand Gulf Rocks we find on the Bayou Taureau a seam of shell limestone with Vicksburg fossils. We then pass over the lignito-gypseous strata to Sabinetown, Texas, where we see about seventy feet of these overlying ledges of blue fossiliferous limestone, alternating every two or three feet with what would be green sand marl, like that of Vicksburg, had not the lime of the numerous shells, of which it contains casts, been removed by subsequent dissolution. So far as I have seen, the usual leading fossils of Vicksburg are wanting here, while the greater sandiness of the materials, as well as the prevalence of shallow-sea bivalves, indicates their deposition in shallower waters." The uppermost fossiliferous strata below the Fayette Beds (Grand Gulf) in Texas are represented on the Brazos by the Moseley's Ferry Beds, and on the Colorado by the White Marl Bluff Beds. Both these deposits show Claiborne and Jackson species, with a tendency toward an increase of the Jackson over the Claiborne as we ascend the series; yet the stratigraphical representatives of these beds in Mississippi and Louisiana contain a typical Vicksburg fauna. Above the Moseley's Ferry and White Marl Bluff Beds are a series of clays with lignite, silicified wood, and other evidences of a land deposit. Similar deposits, but probably developed on a much smaller scale, overlie the Vicksburg strata in the above mentioned States. Consequently it seems possible that while the Vicksburg deposits were being laid down in the Mississippi embayment, a land era existed in the part of Texas just mentioned, and that this accounts for the much greater development in Texas than in the Mississippi region of the fresh water or lagoon clays, which overlie the last marine strata of the Eocene. Hilgard states that the Vicksburg period closed with a more decided tendency to a deep sea fauna than any other epoch of the Eocene. Hence it seems possible that the same oscillation that caused this phenomenon may have also raised the Texas region into a land area. Also the lignitic character of some of the beds of the Vicksburg strata increases very much to the westward, and therefore it would be expected, if this kept up, to run into purely non-marine deposits.†

* "The Old Tertiary of the Southwest," Am. Jour. of Science, Vol. XXX, Oct., 1885, p. 267.

† "On the Geological History of the Gulf of Mexico," American Journal of Science and Arts, Vol. 2, December, 1871, p. 6.

It is, however, too early to theorize on this subject, as the data are as yet very few and scattered. The great stretch of country between the Brazos and the Sabine will doubtless clear up many mysteries.

BASAL OR WILLS POINT CLAYS.

At the base of the Tertiary and immediately overlying the eroded surface of the uppermost Cretaceous strata in East Texas is a great bed of stratified clay, which, on account of its position as the lowermost bed of the Eocene in this region, has been provisionally called the Basal Clays. These underlie a stretch of interspersed prairie and timber land, the country being composed mostly of prairie, with occasional belts and groves of timber. This timber is all hard wood, consisting mostly of post oak, blackjack, and hickory. The belt is sometimes over ten miles wide, and runs between the western edge of the timber and the Central Texas prairies, from the northern part of the State to the Colorado River and beyond. The stratification of these beds is very characteristic, and is very different from the massive structure of the underlying Upper Cretaceous "Ponderosa Marls," but on a weathered surface, where the stratification is not seen, the clays of the two formations are not easily distinguished.* They consist of a stiff laminated clay, yellow, gray, blue, or bluish-green in color, frequently interbedded with seams and laminæ of sand, containing many concretionary masses of gray non-fossiliferous limestone, the latter much cut up by veins of brown crystalline calcite, and varying in size from a few inches to six feet in diameter. They are generally of a flat elliptical shape, and of a gray color. Large quantities of gypsum are also found in places in the clay. On Burnet Creek, one mile east of Wills Point, gypsum crystals five to six inches long are frequently found. One of the most constant characteristics of the clay is the presence in it of soft small white calcareous concretions one-tenth of an inch to two inches in diameter, and often having the cauliflower-like form of some of the geyserite of the Yellowstone Geyser basins. These are found very plentifully, and often collect in large quantities in creek beds. No lignite beds have been seen as yet in these clays.† Such deposits are found well developed at Wills Point, in Van Zandt County. Going east from this place, they are traceable for two and a half miles, when they finally dip under the overlying sandy strata. West of Wills Point similar strata are seen until we reach Rocky Cedar Creek, a distance of five miles. Here is seen a deposit of shell limestone, composed almost entirely of

*The Basal Clays are probably largely derived from the destruction of the underlying Cretaceous strata.

†These clay beds probably represent the Eo-lignitic of Heilprin's Eocene section, the base of Hilgard's "Northern Lignitic" in his Mississippi section, and the Arkadelphia Shales at the base of Hill's "Camden Series" in Arkansas.

shells of Lower Eocene fossils. It is traceable up and down Rocky Cedar Creek for seven miles, and underlies the divide between Rocky Cedar and Muddy Cedar creeks, a distance of four miles. The following section of a well on this divide shows the character of this bed.

1. Sand, gray and buff color	3 feet.
2. Gray and yellow clay (Basal Clays)	9 feet.
3. Shell limestone	3 to 4 feet.
4. Coarse sand	1½ to 2 feet.
5. Shell limestone	3 to 4 feet.
6. Sand in bottom of well.	

About a mile below the point where the Texas Pacific Railroad crosses Rocky Cedar, an outcrop fifteen feet thick of this limestone is seen, and as it still forms the bed of the creek, its thickness here must be still greater than that. The divide between Rocky Cedar and Muddy Cedar is covered with sand as shown in the above section, and is heavily timbered with oak and hickory. The village of Elmo is situated on Muddy Cedar, and just beyond it we come into a black prairie region showing Cretaceous fossils. Consequently the Rocky Cedar limestone is probably the lowermost bed of the Tertiary series in this part of the State, and the line of parting between the Cretaceous and Tertiary strata can safely be placed about at Elmo, or possibly a little west of it. The shell limestone bed is probably of limited extent, occupying no very important stratigraphical position, and appearing at the base of, and as a component part of, the Basal Clays. It is of great importance, however, as showing the geological position of the lowermost Tertiary strata in Northern Texas. The Basal Clay bed in Bastrop County is seen to the west of Elgin, and between there and Manor, in Travis County. It forms the same character of country as in the northern part of the State, and finally disappears to the east under the overlying sands. On the Colorado River it is seen cropping out at a point sixteen miles by river below Austin, and one mile below the mouth of Onion Creek, in a bluff some forty feet high and a mile long. Also at Webberville, on the line between Travis and Bastrop counties, where it is seen in a low bluff just above the water's edge. This is a much darker and more massive clay than that seen in most other outcrops. In the bluff sixteen miles below Austin are found a few fragments of fossils, but they are all so broken as to make their determination very doubtful. The representative of this bed on the Brazos is seen in the bluffs of the river extending from the northeast corner of Milam County down the river to within two miles of Pond Creek, a distance of about seven miles. These clays here overlie the "Ponderosa Marls" which are extensively developed between this point and Waco. They differ somewhat in lithological character from the clays at Wills Point, and are at many places highly fossiliferous. The first

bluff showing them, coming down the river, is in the corner of Milam County. It is about a third of a mile long and forty feet high. The lower part of it is composed of very dark, almost black, clays, containing fragments of shells, and running into a lighter yellowish and greenish clay towards the top. This upper part contains highly calcareous indurated strata, showing a nodular structure and containing many fossils. The lower part of the bluff is also calcareous, but not as much so as the upper part. Dip, three degrees southeast. At a point two miles above Pond Creek is another bluff of interbedded dark gray clays and white and gray sands, containing many flat calcareous concretions, weathering in concentric layers and one to ten feet in diameter. They are dark gray inside and brown on the outside. They are in the sand seams, and are probably simply part of the inclosing stratum indurated by the large amount of calcareous matter that they contain. In a thin bed of clay, four inches thick, in this bluff are found many shells of an oyster. The dip of the bluff is very gentle to the southeast. It becomes much more sandy towards the top than at the base, and doubtless represents the transition bed from the Basal Clays to the great overlying series of sandy strata (Timber Belt Beds.) The extension of the Basal Clays between the Colorado and Rio Grande has not as yet been studied, but it is probable that it becomes much more sandy in that region than it is to the north, as the first Tertiary beds found going down the Rio Grande are very sandy, being composed mostly of siliceous grains and of glauconite. This fact, however, is to be expected, as the Basal Clays doubtless owe at least part of their existence to the clayey matter derived from the Upper Cretaceous marl and "glauconitic" strata, and on the Rio Grande these strata have not undergone so much erosion as those to the north. There is little or no lithological change in the Rio Grande region from the Upper Cretaceous strata to the Lower Tertiary (Laramie?). They both consist of siliceous and glauconitic sands, and therefore, as no unconformity can be seen, the evidence as to a break, if indeed any does exist, in the deposition of the strata must depend upon paleontological evidence. The thickness of the Basal Clays is difficult to determine, as it is rarely exposed in high bluffs, and the vague records of well borings make that source of information unreliable. As stated before, the dip of all the Tertiary strata is so uncertain that no reliance whatever can be placed on estimations of thickness based on it. From an examination, however, of all the details now available, it is probable that the thickness of the strata from the top of the Cretaceous to where the Basal Clays merge into the overlying sandy strata is about two hundred and fifty to three hundred feet.

SOILS OF THE BASAL CLAY REGION.

These soils vary from clay to clay loams, are of a dark gray or black color,

and highly calcareous. They owe their black color to the combination of the carbonate of lime with the vegetable matter on the surface. The soil is underlaid by a subsoil of yellow and gray clays, with occasional thin seams of sand, and many calcareous nodules, which latter supply an endless source of lime. These soils are remarkably rich, and are well adapted for the cultivation of wheat, corn, oats, and other grain crops. Cotton is also most successfully cultivated here; and in fact the soil can support almost any crop that can be raised in the prairies of Central Texas.

THE TIMBER BELT OR SABINE RIVER BEDS.

The Basal Clays, everywhere from the northern part of the State to the Colorado River, blend upwards into the sandy Timber Belt Beds. These form the mass of the Tertiary formation in Texas, and underlie the great timber region of the eastern part of the State. They are composed entirely of siliceous and glauconitic sands, with white, brown, and black clays. The clays, however, are greatly in the minority, and the siliceous sands compose by far the larger part of the whole series. Lignite beds are of very frequent occurrence, varying from a few inches to ten and twelve feet thick; and the sands and clays are often impregnated with vegetal matter to such an extent that numerous traces of petroleum, asphalt, and natural gas have been found in the East Texas region, sometimes in quantities of considerable economic importance. Many of the black and brown clays and sands owe their coloring matter to this ingredient of vegetable material, and burn white or buff color when exposed to heat. These beds occupy an area over 125 miles wide in the northeast part of the State, but thin down to less than 40 miles on the Colorado. This greater development of the Tertiary strata to the northeast is probably due to a greater deposition in the vicinity of the embayment which existed in the lower Mississippi at the time they were laid down. The sands are generally much cross-bedded, gray to buff in color, and contain black specks, which are often glauconite. This latter mineral is a common constituent in many of the beds, and there are found all gradations, from a pure siliceous sand to a pure greensand bed, such as are well developed in the iron ore regions of Anderson, Cherokee, Rusk, and other counties. All the sand beds are more or less impregnated with carbonate of lime, and often it is in such quantities as to form beds of calcareous sandstone, where it acts as a cement, and forms a soft friable rock. Sometimes even beds of limestone are found, and calcareous nodules and concretions are of very frequent occurrence throughout the whole of the Timber Belt Beds. One of the most characteristic features of the region depends on this presence of carbonate of lime in the sandy beds. It is the occurrence of great masses of sand, varying from one to ten feet and more in diameter, and cemented into a hard rock by the

calcareous matter. These rocks vary much in shape and hardness. Sometimes they have a concretionary shape and weather in concentric layers; at others they show the horizontal stratification of the beds in which they occur, and gradually blend into the soft enclosing sand. The presence of this carbonate of lime is due to two sources:

1. The calcareous matter of shells in the strata.
2. The carbonate of lime derived by solution from the old Cretaceous shore line.

This latter source is probably the principal one, as all the waters flowing from Texas into the Tertiary Sea had to pass over hundreds of miles of calcareous strata, and could not help being strongly impregnated with carbonate of lime, not only in solution, but in a state of mechanical suspension. Prestwich* estimates that 290,905 tons of carbonate of lime from calcareous strata resembling those of Central Texas are yearly dissolved in the basin of the River Thames and carried to the ocean in solution alone. From this we can get an idea of the immense amount of the same material that was, and is still, carried down by the Texas rivers. In fact the amount dissolved by a given quantity of water in a Texas river, other things being equal, must be much greater than by the Thames, as the water of the southern streams is much warmer than that of the Thames, and therefore capable of taking up into solution a much larger per cent of carbonate of lime. Doubtless, however, the calcareous matter held by the river waters in suspension has given to the Tertiary strata more carbonate of lime than that in solution, as a large part of the latter would be carried out to sea. This presence of carbonate of lime is of the greatest importance, from an agricultural point of view, to the welfare of East Texas, as it renders soils underlaid by such strata of great fertility and durability; whereas without it, many of them would be perfectly barren. Many of the sands are also intimately mixed with a fine impalpable white clay, which renders the beds soft and highly plastic when wet, but when dry it forms a hard, solid mass, often occurring as a friable sandstone. When such beds are exposed to erosion by creeks and in gullies they break up into lumps, which become rolled and rounded, and form putty-like pebbles. This is a very characteristic kind of erosion in some of the Lower Tertiary strata, and such beds are well developed in central Van Zandt County. The sand beds are generally also variable in composition. They blend by insensible gradations, both vertically and laterally, into clay or sandy clay beds, so that minute correlations, even in beds very close to each other, are difficult to make. This extreme variability in composition is simply one of the many proofs of a near shore deposit. The sand beds often contain consider-

*"Geology: Chemical, Physical, and Stratigraphical," Vol. I, p. 107, by Joseph Prestwich, M. A., F. R. S., F. G. S., London, 1886.

able quantities of dark brown or gray mica. The clay beds of this division vary from a pure white highly plastic clay to a dark brown, or even black, material containing large quantities of lignitic matter. They are generally laminated, or finely stratified, and frequently occur interbedded with thin seams of sand, the latter often in lenticular streaks, while the clay is generally continuous. A very characteristic deposit of this kind is seen underlying the Claiborne greensands in the iron ore regions. The seams of clay vary from one-twentieth to one-eighth inch in thickness, and the sandy seams are but very little thicker. The whole formation shows a peculiar undulating section, the undulations being due to the thinning and thickening of the sandy seams, and not to lateral pressure.* The lignite beds of this series are composed mostly of brown or black varieties, which have not as yet been put to any important economic uses, and which will be treated more fully under "Economic Geology." Silicified wood is of very frequent occurrence in these strata; sometimes occurring as small fragments, and at others as large trunks of trees. On the Brazos River, in the northern part of Milam County, was seen a trunk one and a half feet in diameter, protruding from a clay bed. Ten feet of it were exposed, while the rest was imbedded in the clay. In many places such fragments are collected in great quantities, but it is especially plentiful in the lower part of the Fayette Beds. It is generally dark brown or black inside, and weathers gray or buff color on the outside. Sometimes it occurs partly lignitized and partly silicified. It frequently shows shrinkage cracks which are filled with quartz or chalcedony, and often lined with quartz crystals. Carbonate of iron, in the form of clay ironstone, is of very frequent occurrence throughout the Timber Belt Beds. It rarely occurs in a continuous seam, but is found in lenticular masses and nodules, often occupying the same plane of stratification for considerable distances. Sometimes these masses coalesce into a bed continuous for a few hundred yards. They are rarely over three or four inches in thickness, and are generally rusty from oxidation. They are probably the source of some of the brown hematite iron ores in the counties north of the Sabine River. (See Iron Ores.)

*The sand seams look like a series of connected lenses blending into each other at their edges. This interlamination of sand and clay was caused by the different velocity of the waters that flowed over the beds during their deposition—the swifter waters carrying and depositing the sand and the more sluggish waters depositing the clay. It is natural that such waters as would carry sand would have sufficient velocity to give a gently undulating surface to the beds that they are depositing, and not the smooth level surface of a still-water sediment. Thin beds of clay laid down afterwards on such a surface would naturally conform to the inequalities of the surface, and hence the undulating section that we see does not require the supposition of a lateral pressure for its formation. It seems possible that this same phenomenon may also account for the undulations in many of the old gneissic and schistose rocks, many of which may have once been in the form of sands and clays.

Iron pyrites is an almost inseparable accompaniment of the Timber Belt Beds, and is also the source of many of the iron ores south of the Sabine, as will be explained later. One of the most striking appearances in these beds is the mottled red, yellow, and white character of many of the strata. This is due to weathering, and though it is of very common occurrence throughout the Tertiary, it is also seen in deposits of Quaternary age. The phenomenon is usually brought about in one of three ways:

1. By the oxidation of iron pyrites in the bed, making red or yellow spots, according to the amount of decomposition which that mineral has undergone.
2. By the infiltration of iron-bearing solutions into a white or light colored bed.

When the solution of a soluble salt of iron percolates into a sand bed, it is quickly decomposed by the oxidizing action of the air and precipitated as a red or yellow oxide.

3. By the extraction of iron from a red ferruginous bed through the dissolving action of carbonic acid.

Frequently a ferruginous bed is pierced by the roots of trees, grass, or shrubs, and when these die and begin to decompose they generate carbonic acid. This is taken into solution by the surface waters and dissolves the iron in the enclosing bed, frequently leaving it perfectly white in the neighborhood of the roots. Often the sand or clay immediately around the dead root is white from complete solution or yellow from partial solution of oxide of iron, while the rest of the bed is of a bright red color. When there are many such roots, the sand is often mottled in a most striking manner, and the distance that the light colored sands extend from the root depends on the thickness of the latter. A root an inch thick will often bleach the sand for over an inch on each side of it. This same bleaching action is often brought about by the carbonic acid solutions from the decomposition of leaves and other vegetable matter on the surface of the ground.*

The strata of this series are well exposed on the Brazos and Colorado rivers. These streams run across the strike of the strata in a southeasterly direction, and therefore as we descend them we pass successively from the oldest to the newest beds. The sections seen on them are given below:

BRAZOS RIVER SECTION.

Descending the Brazos River from Waco, we pass over strata of Upper Cretaceous epoch until we reach the northeast corner of Milam County, where

* It might appear that causes 2 and 3 were directly opposed to each other in their action, but such phenomena are influenced in their effect largely by the physical conditions under which they operate, and frequently show directly opposite results.

the Basal Clays of the Tertiary period, already described, are met and extend thence for some seven miles to within two miles of Pond Creek. About a mile and a half below Pond Creek is seen an outcrop of Tertiary sand, containing black specks and rendered plastic by a white clay. It is capped by semi-indurated Quaternary gravel and sand, and contains large nodules which give a strong reaction for carbonate of lime, and which are simply hardened masses of the enveloping sand. They are one to eight feet in diameter, hard, kidney-shaped, flat or nodular, and project out of the compact sandy bluff in a most characteristic manner. Loose fragments of silicified wood, which have also doubtless been derived from the same bed, lie among the many nodules that have been eroded out. So many of these rocky masses have been loosened from the sand and piled up in the bed of the river that they have obstructed its course, and have formed rapids. Many of these rocks are round or oval, and are locally known as "kettle bottoms." Such strata as these are seen down the river for a mile and a half from this point, where they dip under a series of gray clays containing beds of lignite, varying from one to five feet thick and associated with ferruginous sand. The clays contain large masses of silicified wood, which is sometimes seen in places in the bed, but more often has been weathered out and lies in the bed of the stream. Occasionally nodules of clay ironstone, generally in a semi-oxidized condition, are found. Such strata are exposed for about a mile, when the gray sands with calcareous concretions and indurations again appear. This deposit contains considerable quantities of iron pyrites, and the indurations are often cut by veins of crystalline calcite. A short distance below here is Calvert Bluff, Robertson County, where lignite occurs in large quantities and has been worked intermittently for many years. The beds of this strata are shown in the following section:

1. Brown and red river silt	10 feet.
2. Gray clay	0 to 3 feet.
3. Lignite	12 feet.
4. Gray clay	2 feet.
5. Lignite	2 feet.
6. Gray clay	3 feet.

The clay beds in the above section contain large clay ironstone concretions, which enclose many leaf impressions. The lignite is black, woody, friable, and of a dull lustre. It is faulted and much jointed. Dip, three degrees southeast. From here to where the International and Great Northern Railroad crosses the river we see sand beds with calcareous indurations, such as have been described at Rocky Rapids. At this point is a bluff showing sixteen feet of Tertiary strata, capped by over fifteen feet of a highly calcareous light green and yellow Quaternary clay containing many small white concretions.

The base of the Tertiary part of this bluff is composed of black clay from the water edge up to ten feet above it, and is overlaid by six feet of non-fossiliferous greensand marl. The Quaternary deposit lies unconformably on the Tertiary strata. It is to be seen at many points along the river from Falls County down, and is doubtless the representative of an old river silt formation. For twelve miles below this point is seen a series of interbedded and interlaminated clays and sands,* with occasional beds of lignite, and some few small gray calcareous concretions. Frequently small fragments of lignite are seen in the sand beds, showing that the swifter waters, which changed the character of the bed from clay to sand, were also responsible for the destruction of lignite beds, the fragments of which were deposited with the sand.

In the northern corner of Burleson County, and two and a half miles below where the north boundary of the county crosses the Brazos, is seen the first fossil-bearing stratum that has been met along the river below the Basal Clays. Here is found a bluff, about thirty-five feet high, giving the following section:

BURLESON SHELL BLUFF.

1. Fossiliferous greensand marl	10 to 20 feet.
2. Interbedded and interlaminated dark brown and black clays and sands	8 feet.
3. Lignite	2 feet.
4. Gray sand	3 feet.
5. Interbedded and interlaminated dark brown and black clays and sands to water edge	4 feet.

Dip of the above section, 3 degrees southeast.

The greensand marl is rusty and indurated in places, and in others retains its green color. It contains a few gray calcareous concretions, one to three inches in diameter, and is often literally made up of fossils. One mile below this point the same bed is seen dipping under the water level. For six miles below this point is seen a series of interbedded and interlaminated sands and clays, often much colored by lignitic matter, and containing thin seams of woody lignite. The sands are much cross-bedded, and contain considerable quantities of iron pyrites. The dip is irregular and undulating, frequently tending toward the north. Six miles below Burleson Shell Bluff we come to Moseley's Ferry (San Antonio Ferry), where we again find glauconitic deposits rich in fossils. These are twelve feet thick and underlaid near the water edge by a chocolate brown clay containing gray calcareous concretions. The greensand marl is rusty and indurated in places, soft and green in others.

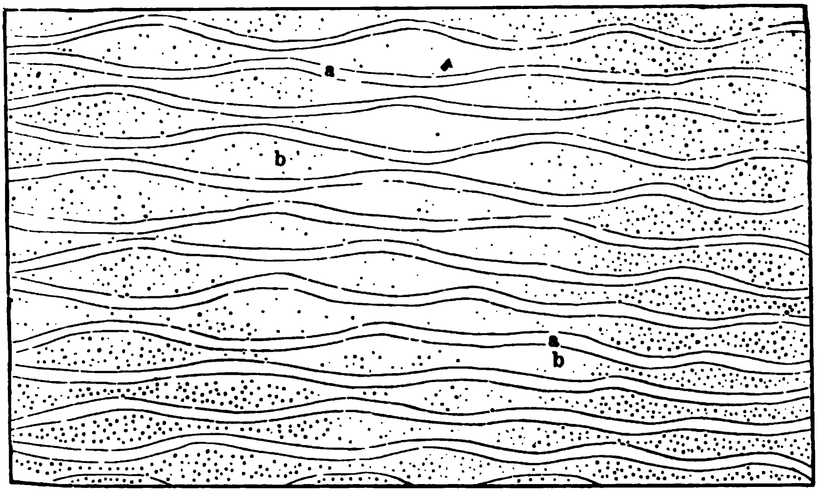
*By this expression "interbedded and interlaminated clays and sands" is meant that sometimes the clays and sands are in alternating beds, several inches or several feet in thickness, and at other times they are in thin laminæ, $\frac{1}{16}$ to $\frac{1}{8}$ inch in thickness. This is a very common occurrence in the "Timber Belt Beds." (See foot note, p. 24.)

Fossils are very numerous, and many species resemble those of White Marl Bluff, on the Colorado. In fact, it occupies the same stratigraphical position at the base of the Fayette Beds, i. e., at the top of the fossil-bearing strata of the Eocene. The next outcrop seen below this appears at the mouth of the Little Brazos River, and is a representative of the Fayette Beds, which will be described beyond.

COLORADO RIVER SECTION.

Five miles by river below the outcrops of Basal Clays already described, in the neighborhood of Webberville, is seen a low bluff, rising some four feet above the water and a quarter of a mile long, composed of glauconitic marl with many Eocene fossils. This represents the lowest fossiliferous bed of the Timber Belt series in this locality. From a point two miles below the Bastrop County line to the town of Bastrop is about twenty miles by river. In this distance are seen numerous outcrops of gray sands, cross-bedded, and containing black specks, which are often glauconite, as well as large concretionary and indurated masses, like those already described on the Brazos at Rocky Rapids. As at Rocky Rapids, they doubtless owe their existence to the presence of argillaceous and calcareous matter, which has acted as a cement. As already stated in the case of the Brazos River rocks, they are simply hardened parts of the enclosing bed. Here, however, on the Colorado they are much fewer and smaller (one to four feet in diameter) than on the Brazos, and form a much less important part in the topography of the river channel. The sand beds are frequently interstratified with beds of gray clay. Many beds of lignite, one to five feet thick, are found cropping out in the bluffs, and thin seams and lenticular masses of carbonate of iron are frequently seen throughout the formation. This latter is generally partly decomposed and exposes a rusty surface. Frequently it shows shrinkage cracks, proving its once gelatinous condition. The dip of these sands and clays is to the east and southeast at an angle of from 0 to 5 degrees. The bluffs are usually capped by from ten to thirty feet of Quaternary gravel and sand.

From Bastrop down the river for eight miles a series of interbedded and interlaminated gray, brown, and chocolate clays and sands is seen in many bluffs. The seams of clay are often not over one-eighth inch in thickness, and yet they preserve a very remarkable continuity; the interlaminated sand occurs as a series of connected lenses, and gives the underlying and overlying clay laminæ the characteristic undulating appearance. (See Figure 1.)



(Scale.—1 inch — 1 foot.)

FIG. 1.—Section of undulating clay and sand strata—a, clay; b, sand.

The dip varies from 1 to 7 degrees, and is very undulating, often showing a local trend to the north. Lignite beds are very plentiful throughout the series and vary from one to eight feet thick. They are generally conformable in a general way with the overlying and underlying strata, but sometimes they are unconformable.

Twelve miles below Bastrop is "Red Bluff." This is about a hundred feet high and capped with a Quaternary conglomerate from three to twenty feet thick, and composed of pebbles of flint, chert, quartz, feldspar, and jasper, one-sixteenth to six inches in diameter, and cemented in a highly ferruginous sand. It frequently contains patches of red and mottled sand, and is of a bright red color. The foot of the bluff is covered by immense blocks that have fallen from this bed. Underneath the conglomerate is a bed of white Tertiary sand, in places thirty feet thick. It is frequently rusted on the surface from the ferruginous solutions running down from the overlying conglomerate. Below the sand are fifty feet of interlaminated seams of chocolate clay, sandy clay, and gray sand. At the base of the bluff the sand bed contains large black indurated masses of sandstone, as at Rocky Rapids, on the Brazos. The whole bluff has a red appearance, the effect of which is greatly enhanced by the patches of unstained white sand occasionally seen. Half a mile below this point is seen a similar though smaller bluff of the same strata. For two and a half miles below this are seen scattered outcrops of gray sands and plastic clays, containing lignite deposits. Bombshell Bluff is seventeen miles by river below Bastrop, and is in the southern part of Bas-

trop County. It consists of thin interstratified layers of glauconitic marl, black clay, and dark siliceous sand with glauconite specks, and is the first fossil-bearing stratum seen since leaving Travis County. Interstratified with these deposits is a hard indurated ledge of calcareous rock, made up largely of glauconite and weathering white. Dark gray round and oblong calcareous concretions are found throughout the clay and sand. The bluff is about ten feet high, and about half way up it is a bed three to eight inches thick, very much rusted and with streaks of hard-pan. This seam is the one which contains most of the fossils, and in some places is almost entirely made up of them. They are largely of the Claiborne age. The sands are cross-bedded and the whole bluff is heavily charged with iron pyrites. Numerous specks of lignite are found, even with the shell-bearing strata, proving beyond a doubt the littoral character of the deposit. The dip is about horizontal. For four miles below this are seen similar ledges of the same strata, all preserving an almost horizontal dip. Frequently gypsum crystals are found in the clays. Four miles below the beginning of this fossiliferous area we come to what is locally known as the Devil's Eye, an eddy at a low ledge of a similar formation to those just described. The strata here belong to the same series as those just passed. The fossil bearing bed is six to twelve inches thick, is semi-indurated, and composed almost entirely of glauconite and shells. Specks of lignitic matter are found throughout the associated chocolate clays, and also, occasionally, small quantities of rusty clay ironstone are seen. Dip, horizontal. Alum Creek Bluff is at the mouth of Alum Creek and a short distance above Smithville. It is forty feet high, and shows the same character of strata and the same shell bed as is seen at Devil's Eye. It is underlaid by twenty feet of much cross-bedded sands, and dips 3 degrees to the southeast. Between here and Smithville is seen a series of interlaminated sands and clays, barren of fossils and dipping 5 degrees southeast. At Smithville, in the eastern part of Bastrop County, are found interbedded deposits of glauconitic marls and chocolate clays in a bluff thirty feet high and capped with Quaternary gravel. The glauconitic marl is hardened and rusty in places, and in others is soft, green, and entirely unaltered. It is highly fossiliferous and contains numerous Claiborne species.* Dip 3 to 8 degrees southeast. One mile below is a small lignite bed underlaid and overlaid by chocolate sands. Below here the river makes a turn to the northeast and again intersects the same bed as is seen at Smithville. White Marl Bluff is near the Fayette County line, is ten feet high and composed of interbedded strata of dark gray clay, glauconite, gray sand, and a creamy white shell-bearing calcareous marl. These beds vary from one to twelve inches thick, and are

* This is the locality referred to by Dr. Buckley "near Mrs. Gazeley's." First Annual Report, Geological and Agricultural Survey of Texas, S. B. Buckley, 1874, p. 64.

all highly fossiliferous. Frequently lenticular beds of hard limestone two to three inches thick and containing considerable iron pyrites occur. This deposit represents the uppermost Tertiary bed containing marine fauna found by the writer on the Colorado. The overlying beds seen farther down the river are treated under the head of Fayette Beds.

The equivalents of many of the beds that have been noted on the Brazos and Colorado rivers are found in many places to the northeast and southwest of those regions, and a careful search will doubtless correlate them with the principal strata described. In a formation of this kind, however, where most all the strata have been laid down either in coastal lagoons or in shallow bays and estuaries, it must be expected to find local changes in the character of the beds, dependent on the source of supply of material in the neighborhood of the special deposit being formed, and also on the very variable conditions which must surround the deposition of such strata. For instance, in many places sandy beds occupy the same horizon that clay beds hold perhaps only a few miles off. Glauconite also varies very much in quantity in beds of the same epoch, and iron pyrites, dependent as it is for its formation on the combined decomposition of organic matter and soluble salts of iron, must from its very mode of origin vary very much in quantity in different parts of the same bed. The same might be said of the various other mineral constituents which characterize these strata, and it is pre-eminently true of lignite beds, which are the result of a certain combination of conditions so local and uncertain in their scope and so liable to exist anywhere in the Tertiary series, that such beds can not be relied on anywhere to determine the horizon of the enclosing strata.

Going northeast from the Brazos, along the strike of the Tertiary beds, we see in Anderson, Cherokee, and Rusk counties extensive glauconitic deposits, rich in Claiborne fossils. These overlie the interbedded sands and clays already described as occurring over the Rocky Rapids sands of the Brazos. The following section, taken three miles north of Rusk, shows the relation of these strata:

1. Gray and buff sands	8 feet.
2. Hard brown sandstone	1 to 3 inches.
3. Brown resinous laminated hematite	1 to 3 feet.
4. Altered fossiliferous greensand	30 feet.
5. Gray clay, stained by iron in places	5 feet.
6. Dark gray sand, with glauconite specks and rusty pyrites, giving rise to many ferruginous springs	20 feet.
7. Gray and chocolate clays, ferruginous in places	35 feet.
8. Interbedded seams of gray and chocolate clay and fossiliferous glauconite marl, sometimes indurated and partly altered; nodules and lenses of clay ironstone	40 feet.

9.	Gray clay, with seams of sand, and some clay ironstone	5 feet.
10.	Interstratified gray and chocolate clay	5 feet.
11.	Lignite	1 foot.
12.	Chocolate clay	1 to 1½ feet.
12.	Lignite	1 foot.
14.	Chocolate clay	6 feet.
15.	Interbedded chocolate clay and small seams of lignite, ⅛ to ½ inch thick, at base of section.	

The greensand bed near the top of the section is probably the representative of the Smithville bed on the Colorado. It is composed of glauconitic grains, with more or less green clay, the latter often occurring in the form of interbedded seams or lenticular patches. The bed is generally rusted on the surface, from the combined decomposition of the glauconite and the iron pyrites that it contains, but the interior preserves its green color. The fossils are generally in the form of casts, but in some places the shells are well preserved, and sometimes, though rarely, oblong and kidney-shaped calcareous nodules one-half to three inches in diameter are found. The bed is of very even thickness, varying over very large areas from thirty to forty feet. This deposit underlies a large part of northern Anderson and Cherokee counties, and forms the dividing ridge between the Angelina River and the Neches, and between the Neches and the Trinity, besides occupying the summit of some of the other highest points in East Texas.

The underlying sands and clays are the equivalents of the beds overlying the Rocky Rapids sands on the Brazos, and also of those below Bastrop on the Colorado. As there, they consist of interbedded and interlaminated sands and clays, often cross-bedded, stained by decomposed iron pyrites, and containing numerous small beds of lignite. These strata are extensively developed all over Cherokee and Anderson counties, and thence on up to the Sabine River, wherever the overlying greensand has been eroded. The sands are frequently indurated by a ferruginous or siliceous cement into beds of sandstone, varying very much in hardness, color, and thickness. The beds with a ferruginous cement vary from yellow to very dark brown in color, and have been solidified by the percolation of water containing soluble salts of iron. The beds with a siliceous cement have been solidified by similar waters containing silicic acid or soluble silicates, and are of a white or buff color. Such beds vary from one to twenty feet thick, and are of very limited extent. They generally cap knolls and hills, and form a protecting cover which saves the underlying strata from erosion. (See Building Stones.) The glauconitic deposit itself finally dips under the overlying clays and sands to the southeast, and gives place to the lignite-bearing region of northern Angelina and other counties.

Some two hundred feet below the iron-bearing greensand bed is a similar

deposit, but without iron ore, and containing glauconite grains which are often as much as one-sixteenth of an inch in diameter. This bed is seen near Jacksonville, and in other places in the northern part of Cherokee County, but no fossil remains have as yet been found in it.

The town of Palestine is situated on a series of glauconitic, sandy, and clayey beds, the greensand containing many Claiborne fossils. Going west, the land gradually drops to the Trinity River bottom, and six miles west of the town we come to the Saline. This is a flat plain one mile wide from east to west and a half mile from north to south. A small stream running through it has lately been dammed up to make a fish pond. Incrustations of saline matter are seen all around the water edge. The surface of the Saline is a black or dark lead-colored clay, like that at Grand Saline, in Van Zandt County. On all sides of the Saline rises a ring of hills reaching sixty feet and more above the pond. In many places on the top and slopes are seen outcrops of a white chalky fossiliferous limestone with dark specks (glauconite). The fossils have been determined by R. T. Hill as belonging to the "glauconitic" beds of the Upper Cretaceous epoch, and possibly represent the Ripley Group of Alabama. [This locality is over fifty miles east of the main Cretaceous area of Central Texas, and doubtless represents the remains of an island* in the old Tertiary sea.] The limestone contains seams of yellow crystalline calçite, varying from a fraction of an inch to three or four inches in diameter.

The limestone is surrounded, and in many cases covered, by the Lower Tertiary clay and by river alluvium. The Tertiary clay is stratified in thin laminæ, sometimes with like laminæ of sand, and is black, gray, or yellow in color. The limestone is not seen continuously all around the Saline, but outcrops in many places, especially on the north, west, and east sides. It is also seen in low outcrops on the south side, but to the southeast the hills are twenty to thirty feet higher than elsewhere, and it is probable that the limestone is concealed under the overlying clay. The clay has been cut in many places by gullies, which head at the ledge of limestone, and show the latter to have a very abrupt slope. Capping the limestone in some places is a more or less ferruginous brown shell rock one to twelve inches thick. It is full of indistinct shells, or casts of them in calcite, and in places is very sandy. It is not found in a continuous bed, but as flat fragments, very numerous in some places and entirely wanting in others. Overlying this, and sometimes attached to the fragments of it, is a yellowish dun-colored sandstone, in flat slabs one-half to three feet thick. It is probably the indurated part of an

* Lawrence C. Smith mentions several other localities of similar islands in East Texas, but they have not yet been visited by the writer. "The Iron Ore Region of Northern Louisiana and Eastern Texas," by Lawrence C. Smith, pp. 22, 23.

eroded bed of sand which once overlay the shell rock, and the latter probably represents the lowermost Tertiary bed which once overlay this exposure of Cretaceous rock in a continuous stratum. The Saline was worked for salt several years ago, and some large shallow wells were sunk in the clay to collect brine. But lately cheap Eastern salt has driven it out of the market. Seven miles south of Palestine is seen a deposit of white cross-bedded sands, very much like those seen at "Red Bluff," on the Colorado River. They are exposed in numerous gullies and washouts. Between here and Palestine are seen many outcrops of clay and sandy strata, and occasionally the hills are capped with the iron-bearing glauconitic beds.

One mile south of Elkhart, in Anderson County, numerous fossils are found in glauconitic strata in the bed of a small creek; beyond them are seen clay and greensand beds belonging still higher up in the geological series. From data obtained at these localities the following section can be made:

1. Brown and black clays, plastic, containing irony pebbles, silicified wood, calcareous nodules	10 feet.
2. Gray and yellow brown plastic clays in thin laminæ	5 feet.
3. Dark brown altered greensand, fossil casts, probably	1 foot.
4. Gray laminated plastic clay	3 feet.
5. Greensand, hard for eight to ten inches and full of shells, interbedded with greenish black clay	4 feet.
6. Gray clay like (4), base of section.	

One mile southeast of Elkhart several wells, thirty to sixty feet deep, have been sunk for mineral water in strata which, geologically, belong directly under these.

HOUSTON COUNTY.

Two miles west of Crockett, the county seat of Houston County, is Cook's Mountain, a hill about six hundred yards long, rising gently from the southeast and ending abruptly on the northwest. It is capped by a yellow sandstone containing many shell casts, is cross-bedded, and made up of grains of sand, mica and glauconite. It is underlaid by gray and brown laminated clays. Nine miles northeast of Crockett, on the old San Antonio Road, is an outcrop of shell-bearing rock similar to that seen one mile south of Elkhart. It is overlaid by very dark lead-black plastic clay, with white calcareous concretions, and small fragments of silicified wood. The calcareous concretions are soft and jelly-like when freshly dug, but harden on exposure to the air, causing cracks which are often filled with crystalline calcite.

MARION AND CASS COUNTIES.

At Port Caddo, on the Big Cypress River, are found large concretionary masses of limestone, varying from two pounds to two tons in weight. They

are gray in color, compact, very hard, and often semi-crystalline. They are buried in a light clay, frequently sandy and containing small seams of lignite. They are often rusty on the outside, and weather in concentric layers. From here in a westerly direction to Jefferson, a series of sands and clays is passed over frequently containing ferruginous seams or glauconiferous strata and lignite in small quantities. Going north from Jefferson similar sands and clays are passed over, containing considerable quantities of clay ironstone and brown hematite. The ore usually caps the hills and gives the same characteristic topography as is seen in Cherokee County and elsewhere. The clays and sands are frequently mottled red, yellow, and white, and are much cross-bedded. Continuing into Cass County, similar deposits are seen along the line of the Texas and Pacific Railroad, near Springdale, Atlanta, and other places. At Alamo, in the northeast part of the county, a shaft has been sunk for lignite and shows the following section:

1. Sand and clay	26 feet.
2. Gray clay	23 feet.
3. Lignite, black and often glossy	1 foot 8 inches.
4. Gray sand	2 feet.
5. Hard slaty clay	9 feet.
6. Lignite	4 feet 2 inches.

Going west from Jefferson a series of sands and clays, mostly the former, is passed over until we reach the Basal Clays, three miles east of Wills Point. Such strata are seen at Hawkins, Neals, Wilkins, Gladwater, Longview, Marshall, and other places. These sands and clays belong to the Timber Belt Beds, and contain many seams of lignite, which crop out in the bluffs of the Sabine River in Van Zandt, Rains, Wood, Smith, and other counties, as well as in many creeks and wells. In Van Zandt County are seen numerous outcrops of gray sand intimately associated with an impalpable white clay. When wet, it is soft and putty-like, but in a dry state it becomes hardened, and stands up through the surrounding and more incoherent strata like a reef of rock. Such a deposit is seen two miles southwest of Bolton, on the Wills Point and Edgewood road, and probably represents the sand beds seen at Rocky Rapids, on the Brazos. At Grand Saline, in Van Zandt County, on the Texas Pacific Railroad, is a large deposit of salt. It has been found in boring at a depth of two hundred feet, and the salt bed has been bored into for a hundred and twenty-five feet without reaching the bottom of it. The overlying strata are Tertiary clays and sands. Salt was gotten over thirty years ago from brine which rose in shallow wells ten to twenty feet deep in the surface of the Saline, but is now obtained by the evaporation of the much stronger brine from the deep borings. The Saline is about one mile long from east to west, and about a half mile wide from north to south.

Saline Creek runs just southeast of the southeast corner, and thence into the Sabine River, about three miles to the northeast. Along this is a series of flat swamps, heavily wooded with thickets, and subject to the overflows of the river. To the north, south, and west the land rises slowly into the sandy hills of the Timber Belt Beds.

HENDERSON COUNTY.

At Athens, the county seat of Henderson County, are seen similar sandy and clayey strata to those described in Van Zandt County. The following section, made up from data collected to the east and southwest of the town, shows the character of the bed:

1. Ferruginous clayey sand, with thin seams of iron ore two to twelve inches thick	5 feet.
2. Gray clays and ferruginous sands	23 feet.
3. Potters clay	12 to 18 feet.
4. Siliceous sands and gray clay, in some places pure, in others ferruginous	78 feet.
5. Lignite	3 to 4 feet.
6. Chocolate colored clay	3 to 4 feet.
7. Gray clays and sands at base of section.	

TIMBER BELT SOILS.

The soils of the Timber Belt Beds differ very much, and vary from the rich dark river bottom clays and loams to the sandy lands of the upland plateaus. Between these are the red and mulatto soils of the intermediate region. These soils may be described under five headings:

1. Chocolate soils	River Bottom soils.
2. Red Clayey soils	Lowland soils.
3. Red Sandy soils	
4. Mulatto soils	
5. Gray sandy soils	Upland soils.

The river bottom soils, or chocolate lands, are found along all the rivers, and are alluvial. They vary from the clayey to the sandy class, but generally belong to the former, differing a little in color, according to the local presence or absence of iron. They are frequently highly calcareous, especially along the larger rivers, which, having previously flowed over vast areas of calcareous rocks in the prairie region, have become highly charged with carbonate of lime. When the rivers rise in the wet season they overflow this bottom land, leaving a sediment of rich calcareous clay, which adds greatly to the fertility of the soil. The red clayey, the red sandy, and the "mulatto" soils are extensively represented in East Texas, and form some of the richest

lands of the region. They are not sharply divided from each other, but gradually blend together. They are underlaid by the clay and sandy strata of the Timber Belt Beds, and owe their color to the decomposition of glauconite and other iron-bearing minerals.

The "mulatto" soils are of a brownish red color, and are generally the result of the decomposition of the large glauconite beds of the region, and as they contain the fertilizing ingredients of that mineral, they are very productive. Next to the river bottom lands, they are the most productive soils of East Texas, and are extensively developed in Anderson, Smith, Cherokee, Rusk, Gregg, Harrison, and other counties.

The upland soils, or gray sandy lands,* cap the high plateau country. They are of a gray or buff color on the surface, but one-half to two feet below the sand becomes much more mixed with clay, and is often stained red by iron. The gray surface soil blends into and is doubtless derived from the red subsoil, but has lost its iron by the leaching action of carbonic acid solutions. The clay has also been carried away on the surface by the action of rain water. The early settlers avoided these high sandy lands, as they were considered barren and worthless. But with an increase of population came an increase in the value of land, and a corresponding necessity to use all available soils. Then it was that these uplands were tried and found especially well adapted to the cultivation of fruit. Such lands overlie the great iron ore ridges of Cherokee, Anderson, Marion, and other counties, and doubtless owe their agricultural value to the clay subsoil.

ANALYSES OF SOILS.†

Analysis Number.	Volatile Matter.	Soluble Silica.	Insoluble Silica.	Oxide of Iron.	Alumina.	Phosphoric Acid.	Lime.	Magnesia.	Sulphuric Acid.	Carbonic Acid.	Chlorine.	Soluble Potash.	Insoluble Potash.	Soluble Soda.	Insoluble Soda.
1.....	6.10	0.23	72.09	16.99	2.78	0.23	0.28	0.22	1.54	....	0.10	0.09	0.013	0.15	0.24
2.....	10.39	0.25	59.14	25.73	3.14	0.44	0.16	0.30	0.31	....	0.11	0.04	0.19	0.09	0 37
3.....	0.65	0.33	71.15	3.20	1.77	0.14	11.20	0.09	1.20	8.70	0.09	0.00	0.13	0.10	0.29
4.....	7.04	0.29	87.61	1.44	0.67	0.07	0.97	tr'ce	0.57	....	0.14	....	0.09	0.11	0.06
5. ...	2.91	0.38	86.02	1.64	0.69	0.18	4.14	tr'ce	1.44	1.60	0.11	...	0.11	0.02	0.21
6.....	4.74	0.36	81 70	1.92	1.74	0.19	4.89	0.29	0.34	3.30	0.08	....	0.14	0.28	0 22

† By P. S. Tilson, Chemist to the State Geological Survey at A. and M. College of Texas.

Nos. 1 and 2 are "mulatto" soils from northwestern Cherokee County.

No. 3 is a Brazos River bottom black clay soil from Milam County.

No. 4 is a Brazos River bottom yellow clay soil, Brazos County.

Nos. 5 and 6 are Brazos River bottom reddish-black clay soils from just above the mouth of the Navasota River.

*These soils must be distinguished from lowland gray sandy soils, which are often very unproductive.

RIO GRANDE SECTION.

The beds on the Rio Grande, which stratigraphically seem to represent the Timber Belt Beds to the northeast, come in direct contact with the Upper Cretaceous glauconitic beds without any interposition of the Basal Clays. Possibly a study of the paleontology may prove the existence of the equivalent of these beds in that region, but their lithological representatives are not there. Though considerable collections of fossils have been made in this country, and are now in the hands of Professor Angelo Heilprin, they, unfortunately, have not, at the time this report must be published, been thoroughly studied, and therefore the position of the so-called "Laramie" on the Rio Grande will have to be left for future discussion. It may be said, however, that Cretaceous fossils have been found at Eagle Pass, and from there down the river to the Webb County line are found great quantities of *Ammonites*, and other fauna of that epoch. In fact, it is not until we reach a point three miles below the northwest corner of Webb County that true Tertiary (or Laramie) forms are found. Supposing the Cretaceous and Tertiary parting to cross the river at this point, we would do away with the much mooted question of the westerly extension to Las Moras Creek, above Eagle Pass, as drawn by Loughridge,* Conrad, and others, and the slight deflection to the west could easily be accounted for by the supposition of an embayment on the Rio Grande at the time of the deposition of these strata similar to that which existed at the same time on the Mississippi. Rœmer† makes the line of parting cross the Rio Grande at Presidio de Rio Grande, ten miles above Laredo, while Schott‡ refers to all the country from the mouth of the Pecos to the Gulf of Mexico as the "Cretaceous Basin of the Rio Bravo" (Rio Grande). It seems probable now, so far as can be judged without a further study of the fossils, that Rœmer was nearer right than the others, and that, as has been pointed out by Hill, the line as drawn by Conrad was based on certain Tertiary fossils which had been misplaced in the collection.

The mineralogical constituents of the Upper Cretaceous and the Lower Tertiary (or Laramie) formations on the Rio Grande are very much alike, and nowhere can there be seen a break or an unconformity. It appears, so far as the lithological character of the rocks goes, to have been a continuous sedimentation from Eagle Pass to the sand beds, reaching down to below Roma, a distance of over 325 miles. The beds of course vary slightly in

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* "Report on the Cotton Production of the State of Texas," Tenth Census of the United States, Vol. V., p. 679.

† "Contributions to the Geology of Texas," American Journal of Science and Arts, Second Series, Vol. VI, p. 21, 1848.

‡ Mexican Boundary Survey, Vol. II, Part II, Chapter II, p. 28.

character from one place to another, but no decided change is seen. The strata are composed of gray or buff colored sands in various degrees of induration, from a loose material to a hard sandstone, and sometimes even to a semi-quartzite, and associated with minor seams of gray or brown clay and hard shelly limestone containing many fossils. Occasionally beds two to ten feet thick and composed almost entirely of the shells of oysters are seen, doubtless representing a littoral formation. The sands are composed largely of pure siliceous grains, always containing specks of glauconite, which sometimes increase in number until they compose the mass of the bed. The cementing material is usually carbonate of lime, which is here in much greater quantities than in the corresponding strata to the northeast. Sometimes the sands are cemented by silicic acid, and in such cases they form the hard semi-quartzite rocks mentioned above. The climatic conditions in this warm, dry region are such as to indurate rocks containing a cementing material much more than the comparatively cool and moist climate to the northeast, and the consequent greater hardness of the strata gives a much more rugged, angular, and imposing topography to the country than is seen in East Texas proper. The almost entire absence of timber of any kind tends still farther to enhance the effect of this configuration. Springs are practically entirely absent, and creeks are very rare, though their dry beds are seen in many places, and the heaps of pebbles in some of them prove the great torrents that sometimes come down them. They run through narrow canyons thirty to eighty feet deep and with very steep sides. This form of channel is doubtless due to the meteorological conditions of the region, which consist of long drouths of many months at a time, suddenly ended by spasmodic downpours. The country is seen to consist of a great table land sloping gradually to the southeast, and much cut up by dry creek and river beds. It is in fact the southwestern continuation of the East Texas table land already described, though as it has not been exposed to so much erosion as that region, it shows a greater surface of the original plateau. Timber is very scarce throughout the Rio Grande region, except directly on the river banks. At Eagle Pass the only vegetation is mesquite and cactus, with occasional areas of mesquite grass. The mesquite trees are generally scrubby and low, though sometimes trunks one foot in diameter are seen. On the river bluffs are also found hackberry and cane. Half way between Eagle Pass and Laredo, willow becomes plentiful, and increases on down to Brownsville. No large specimens are seen, as on the Brazos, but it often occurs in dense scrubby thickets. Cane is plentiful all along the river, and is especially dense on the water's edge, disappearing a few yards back and giving place to the cactus and mesquite. This character of vegetation continues to Carrizo, where we see the first cypress, forming a grove just below the mouth of the Salado River, on the Mexican side.

From here to Roma many other scattered cypress trees are seen, and are said by Schott* to be colonies from other groves some distance up the Salado. Below Carrizo, grass becomes more plentiful, and as we approach Rio Grande City and Hidalgo, the low bluffs are often capped by rich grassy sod. The willow here often entirely replaces the mesquite along the lower bluffs, and the general appearance of the country is that of a better watered land than up the river. This is especially true of the country about Brownsville, where luxuriant corn fields are to be seen, as well as cotton and sugar cane plantations and fine grass lands; all, however, assisted by irrigation.

Though, as has been shown, the strata on the Rio Grande differ somewhat in physical character from those of the country to the northeast, yet the composition, dip, and the general make-up of the beds are remarkably similar to their stratigraphical counterparts in that region. In both places we see everywhere the signs of alternating marine littoral and brackish water lagoon formation in the great banks of shells, the littoral character of the fauna, the ripple-marked sands, the lignites, and the worn fragments of lignite even in some of the shell-bearing beds. There is, however, one striking difference: On the Rio Grande the marine character of the strata predominates, while in Northeast Texas the lignitic or lagoon character occupies the vast bulk of the strata.

At Piedras Negras, directly across the river from Eagle Pass, are interbedded siliceous sands, sometimes containing large quantities of glauconite and thin seams of lignitic matter. The strata are undulating, and are capped by gray river silt, some twenty feet thick. On the American side of the river, a half mile northwest of Eagle Pass, is found a series of light brown or buff semi-indurated calcareous sandstones, containing Cretaceous fossils. This formation composes an abrupt and flat-topped ridge, rising some seventy-five feet above the town, and running off in a southeast direction towards the river, with a gentle dip in the same direction. One mile below Piedras Negras, on the Mexican side of the river, are found deposits similar to those at that town, but here they contain trunks of silicified wood, and large indurated masses, as seen on the Colorado. Just below Rio Escondido is found a low bluff of stiff greenish clay, resembling very much the "Ponderosa Marls" of the Upper Cretaceous. A quarter of a mile below, on the same side, are seen interbedded sands hardened into flat slabs three to ten inches thick, containing many shells, interbedded with gray sands, and dipping three degrees southeast. The same formation is seen for a mile and three-quarters below this, and on both sides of the river. At this point there are found, on the Texas side, numerous *Ammonites* and other fossils in a hard gray limestone. The series consists of the same sandstone as the last. Six miles below, on the Texas side, is seen

*Mexican Boundary Survey, 1857, Vol. II, Part II, Chap. II, p. 43.

a similar formation to that in which the *Ammonites* above referred to were found. Large blocks of limestone, with flat and bedded slabs of gray sandstone, are seen, and many fossils similar to those seen above. A quarter of a mile below this, on the Texas side, is a bluff sixty feet high, composed of beds of friable sandstone, hard shell limestone, with great numbers of oysters, and softer sand and sandy clay strata. The shell rock is in places entirely composed of fossils. From here to a point five miles below Las Cuevas Creek, in Maverick County, are found a great number of bluffs, showing a similar formation of sands and clays. The bluffs rise from ten to a hundred feet above the level of the river. They are capped by pebble beds one to five feet thick, which in turn are sometimes covered by five to fifteen feet of gray river silt, containing recent land shells. The pebbles are composed of limestone, flint, quartz, chalcedony, agate, black obsidian, jasper, and red pitchstone. The sandstones vary from a friable rock to a quartzite, and often layers of hard shell limestone or beds of oysters two to four feet thick occur; also, many Upper Cretaceous *Ammonites* are found in various places. Islands are of common occurrence, and are composed either of river silt or of the older strata. All the bluffs dip horizontally, or from one to three degrees to the southeast.

At a point five miles below Las Cuevas Creek are the Angostora Rapids. These are caused by a reef of oyster shells, of the same kind as mentioned above, which run across the river, and are covered on either bank by the same gray or buff sandstones. For sixteen miles below here, by river, we find almost uninterrupted outcrops of similar deposits of dessicated and indurated sands and clays, containing many *Ammonites* and other forms similar to those found at the Cretaceous exposure in Anderson County (pp. 33–34). At this point we come to what is known as Las Isletas. The river is a half mile wide and very shallow. It is full of small islands, consisting of sand bars, and covered by mesquite and cane. The bottom of the river is rocky, and causes almost continuous rapids for five miles.

For twelve miles below Las Isletas, and to a point three miles below the north line of Webb County, we see many outcrops of a formation similar to those already described, and with similar fossils. But here the fauna changes, and the character of the strata becomes more glauconiferous. The following section shows the character of the bluff at this point:

WEBB BLUFF.

1.	White indurated fine sandy clay, with dark streaks, and specks of lignitic matter	30 feet.
2.	Greensand marl, with many Tertiary fossils, nodules of carbonate of lime containing glauconite specks	7–8 feet.
3.	Stiff plastic bluish-black clay, jointed, specks of mica	10 feet.

Dip of strata 3 degrees southeast.

This is the first outcrop which has a Tertiary appearance. A quarter of a mile below is a bluff fifty feet high of indurated sandy clay, containing mica and ferruginous scales between the strata. Dip 1 degree south. One and a half miles below are seen similar deposits, but with no fossils, and containing numerous gray calcareous concretions with veins of brown crystalline calcite. Two miles beyond this, on the Mexican side, is a bluff, a quarter of a mile long and seventy-five feet high, of interlaminated gray sands and chocolate clays, with sulphur and gypsum in places, and occasional ferruginous spots. Hard gray clay ironstones with leaf impressions are also found. The sand beds are from one to five feet thick, and the clay is in thin laminæ. Dip undulating from 1 to 5 degrees southeast. These bluffs have a decided Tertiary appearance. The mica and black specks in the sand, the laminæ of chocolate clay, the presence of sulphur and gypsum crystals, all show a strong resemblance to the Tertiary of East Texas. From here to the Hardin Ferry, and thence to the mouth of the Cavezeras River, are seen similar strata, frequently causing rapids where they cross the Rio Grande. In one place the indurated bluffs encroach on the river until it narrows down to thirty yards. Here the waters have cut a deep channel and rush through at a great velocity. Frequently interbedded glossy brown ferruginous layers, one to two inches thick, are found in the sandstone. Three miles below "the Hardin" is a bluff sixty feet high composed of friable standstones, the harder and softer layers blending into each other and occasionally showing ferruginous patches. Dip 1 degree south. For nineteen miles below this point we pass over identically similar strata, frequently containing calcareous concretions one to three inches in diameter. These contain seams of crystalline calcite, and are of a gray color, weathering brown or red in concentric layers.

At a point eight miles above the Texas town of Palafox, and on the Texas side, the following section was seen:

1.	Siliceous sand, colored red, yellow, and purple in seams	40 feet.
2.	Light green clay, with specks of black mica	10 feet.

In 2 was found the impression of a palm leaf, very similar to those found at Palm Bluff, on the Colorado. The bed containing it is also very like those of the "Fayette Beds" at that place. As true Eocene-Tertiary strata are found below here, this bed must either not belong to the Fayette series, or else it is an isolated deposit far inland from the westerly edge of the main outcrop. Palafox is thirteen miles above the San Tomas coal mines and directly opposite the Mexican town of Hidalgo.* The latter place is on a ridge thirty to fifty feet high and a half mile long, composed of the same sandstone as is seen above. Dip almost horizontal.

*This town is not the Hidalgo in Hidalgo County; the latter is in Texas.

Similar strata are seen from here to the San Tomas coal mines.* These are situated on the Texas side of the river and at the mouth of San Tomas Creek, about twenty-five miles by river above Laredo. The following section shows the occurrence of the coal:†

1.	Calcareous sands	12 feet.
2.	Friable sandstone	12 feet.
3.	Chocolate, gray, white, and brown clays, with sulphur and gypsum crystals in layers, running downward into black clays, with a two-inch seam of woody lignite a few inches above 4.	10 feet.
4.	Coal, massive glossy black conchoidal fracture, but sometimes having the form of bituminous coal	1½ feet.
5.	Hard black clay	2 inches.
6.	Coal, same as 4	1½ feet.
7.	Gray clays containing lignite seams, directly under the coal	10 feet.

For three miles below this are seen indurated greenish clays with leaf impressions, broken stems, and specks of lignite. Occasionally seams of chocolate clay and calcareous nodules are found. As usual, the bluffs are capped with pebbles or sand, and dip two degrees southeast. Fifteen miles above Laredo is a bluff reaching a maximum height of forty feet, and about a mile long. It is composed of interbedded coarse sand with calcareous nodules, and sandy clay with gypsum and sulphur. The sand grains are red, yellow, white, and gray, and the whole bluff has a greenish appearance, spotted in places by ferruginous matter. Many similar outcrops are seen for seven miles below, and as the dip is often horizontal, or nearly so, the exposures show simply different parts of the same bed. Eight miles above Laredo is a bluff about eighty feet high and a half mile long, composed of semi-indurated buff sands with an undulating dip. Similar exposures are seen down the river to Laredo, and in fact that town is built partly on the same beds. In limestone from this place Professor Heilprin has found *Cardita densata*, *Turritella carinata*, and other Claiborne fossils.‡ One mile below the town are seen highly calcareous sandstones, soft on a weathered surface, hard and flinty inside, and associated with chocolate clays. Large quantities of iron pyrites are found all through the formation, as well as specks of lignite, grains of glauconite, and often an efflorescence of sulphur. Five miles below Laredo, a large bed composed of fragments of an oyster was found in the following associations:

*Dr. C. A. White refers the coal of Maverick and Webb counties to the "Fox Hills" or to the "Laramie" formation. American Journal of Science, Vol. XXXIII, p. 19, January, 1887.

†For description of coal, see "Economic Geology.."

‡"Contributions to the Tertiary Geology and Paleontology of the United States."

1.	Oyster bed, containing fragments of oysters cemented in greensand marl.....	1–2 feet.
2.	Softer greensand marl, with a few oysters, *Turritella*, shark teeth, etc......	2 feet.
3.	Interlaminated gray and chocolate sandy clay with sulphur...............	2 feet.
4.	Greensand marl to water edge.....	1½ feet.

Below this point for five miles similar deposits are seen, and here we come to another highly fossiliferous bed consisting of interbedded siliceous sands, chocolate clays, and greensand, in a bluff fifty feet high. Half way up is a bed composed mostly of shells in a greensand matrix, and eight to twelve inches thick. In it were found many oysters, *Turritella* and other gasteropods. Hard gray calcareous nodules, like those at "Bombshell Bluff," on the Colorado, and containing specks of lignite, are found throughout the section. One mile below, and on the Mexican side, is a bluff thirty to fifty feet high, and extending down the river for a mile and a half. It is composed of interbedded gray sands, with specks of glauconite, and chocolate and gray clays, containing thin lenticular seams of lignite one-eighth to one-quarter inch thick, and a few fragments of shells; also gray calcareous concretions one to two inches in diameter, and gypsum crystals. At its lower end this bluff runs into a somewhat similar formation, but differing from it in having many colored sands in seams of purple, red, yellow, brown, and bluish-gray. Considerable quantities of iron pyrites are present, and it is probably to this that much of the coloring matter is due. Two miles below here the strata again assume their normal character, and dip two degrees southeast. About at the line between Webb and Zapata counties is a bluff a mile long, and reaching a maximum height of a hundred feet. It consists of buff and greenish-colored sands with gray calcareous concretions, one to ten feet in diameter, and many large gasteropods, one to four inches long, in a hard shell rock at the base. Near the top of the bluff is another shell bed, six to eight inches thick, lenticular, and made up mostly of fossils, among which are many *Turritella* and *Cardita*. Similar bluffs, but without fossils, are seen almost continuously down the river, on the Texas side, for two miles.

At the mouth of Arroyo Dolores are found glauconiferous beds with many oysters, in places made up entirely of them, with apparently no other fossils, and rising ten to thirty feet above the water. Thirteen miles above San Ignacio is seen a low reef of hard gray limestone, weathering to a greenish-gray color, and rising two feet above the water. It shows a concretionary structure in places, and forms rapids in the river. Four miles below this is a bluff three hundred yards long and varying from twenty to sixty feet high. The upper third of it is composed of river alluvium, with a pebble bed at its base. The lower part consists of buff sands and sandstones, with seams of chocolate clay and greensand. The top of this deposit is capped by a shell bed containing glauconite, and six to eight inches thick. Among the fossils were found

Cardita, *Crassatella?*, oysters and shark teeth. The shell bed contains specks of lignite, and the shells are mostly in fragments. Small white calcareous concretions are numerous. Dip, 1 to 2 degrees southeast.

Similar outcrops, but non-fossiliferous, are seen down the river to a point twelve miles below San Ignacio. The sandstones vary from very friable to hard and compact, and often loose masses lie on the slopes of the bluffs like slabs of flagstone. Throughout this whole distance of twenty-one miles the strata all dip to the northeast at an angle of from 1 to 10 degrees, and in one place, five miles below San Ignacio, they dip 10 degrees northwest. This is the greatest and longest variation in the normal southeast or east dip that has been seen by the writer anywhere in the formations under discussion. The strata do not show any other evidence of having been upthrown or disturbed in any way, and it seems probable that this abnormal dip is due simply to the natural sinking and contraction of the strata as explained on page 16. Below here on the river are seen many local dips to the northeast of 5 to 8 degrees, but they never prevail for more than a mile or so. Four miles above the Texas town of Carrizo, and on the Mexican side of the river, is seen a bed of woody lignite one and a half to two feet thick, overlaid by ten feet of buff sands and underlaid to the water's edge by four feet of greenish-gray clay. The Rio Salado flows into the Rio Grande from the Mexican side opposite Carrizo. The town of Guererro is on this river, six miles from the mouth, and in this distance are seen many outcrops of buff sandstone, often rising in abrupt ledges through the river alluvium. Most of the houses, churches, and fences of the town are built of it. Similar rocks are seen for sixteen miles below Carrizo on the Rio Grande, and dip at an angle of 2 to 6 degrees southeast. At this point a small creek on the Texas side cuts through a series of low ledges of interstratified buff sandstones, containing gray concretions and chocolate black and greenish-blue semi-indurated clays, dipping 1 to 2 degrees southeast. In the bed of the creek were found many fossils, mostly oysters, and fragments of silicified wood. Thence down the river for nine miles similar, but unfossiliferous, ledges are seen. At the end of this distance is a bluff forty feet high, composed of interbedded hard and soft calcareous sandstones and clay seams, and containing many *Cardita* and *Crassatella*. Numerous calcareous concretions are found, and the sand occasionally contains coarse black and gray siliceous grains the size of a mustard seed and larger. Three miles below here, and half a mile above the Starr County line, is a low bluff composed of gray clay and capped by a bed, six to eight inches thick, of shell rock with specks of glauconite, *Cardita*, and many gasteropods (*Turritella, etc.*). Eight miles below the western line of Starr County the following section was seen:

1. Indurated light brown sand	3 to 6 feet.
2. Loose light brown sand	10 feet.
3. Gray clay	5 feet.
4. Oyster bed, *Ostrea georgiana*?	10 to 12 inches.
5. Gray clay	1 foot.
6. Oyster bed, *Ostrea georgiana*?	1 foot.
7. Detritus to water edge	4 feet.

Beds 4 and 6 are a solid mass of shells. Some of the oyster shells are over one foot long. Dip of strata varies from horizontal to 3 degrees northeast. Eight miles above Roma are seen similar beds, associated with similar clays, and dipping 2 to 3 degrees south. Two miles below this point, on the Mexican side of the river, the following section was seen:

1. Greenish-yellow hard clay, with white calcareous concretions, gypsum, and sulphur, indurated in layers one to three inches thick	20 feet.
2. Oyster bed, same as described above, in a white calcareous rock	2 feet.
3. Same sands and clays as in 1	18 feet.
4. Brown and black lignitic clay, with gypsum and sulphur	6 feet.
5. Siliceous sandstone, rusty and hard in seams, gray to brown in color, and containing much sulphur as it approaches bed 4	10 feet.

Dip of strata 7 degrees southeast.

The bluff varies from ten to thirty feet in height, and is a half mile long; the above section is taken along three hundred yards of it. Two miles below this, on the Mexican side, is seen an oyster bed, in the same associations as in the above section. It is ten feet thick, and contains a seam of clay in the lower part. The bed immediately overlies the brown and black clays of the last section. Dip, 0 to 2 degrees northwest. Four miles below, on the Texas side, are seen ledges and reefs of similar shell beds, and in some cases single shells are as much as eighteen inches long. Dip, 5 degrees west. The same formation runs hence to Roma, but at that place only a few of the large oyster shells are seen scattered through the buff sandstone. One and a half miles below Roma are seen the same strata as at that town, and dipping 7 degrees east. At this point we come into a great clay and sand area, nonfossiliferous, and resembling the Fayette beds ("Grand Gulf") of the Colorado River. It seems exceedingly possible, however, that the oyster-bearing strata above and below Roma, and even some of the beds as far up as the mouth of the Salado and above in the isolated localities mentioned, may come under this head. They resemble the Fayette Beds very much in lithological character, and all contain the characteristic clays of that epoch. The large oysters mentioned above have not been found in East Texas, and therefore the strata containing them must either be wanting there, or must represent the base of the "Fayette Beds" of that region. Another argument in favor of the supposition of the extension ot the Fayette Beds up the river is that if

we place their inland limit below Roma, the line of separation on the Rio Grande between the Fayette Beds and Timber Belt Beds would curve outward toward the Gulf of Mexico, whereas we should expect it to curve inward, just as the line between the Cretaceous and the Timber Belt Beds does, on account of the probable embayment on the Rio Grande at the time of their deposition. These beds lying between here and the coastal region will be treated under the heading of "Fayette Beds." A more detailed discussion of the Rio Grande strata is reserved until the fossils have been thoroughly studied.

THE FAYETTE BEDS.

These beds underlie the interior part of the coast plains of East Texas, and as we near the Gulf shore they are seen to gradually dip under the Post-Tertiary deposits. The surface of the country consists of a rolling prairie, and parts of it are undoubtedly destined to become very rich agricultural regions, combining as they do all the advantages of a rich soil, a well-watered country, and the temperate climate of the sea coast.

The thickness of these strata is at the minimum 350 feet, and probably nearer 400. They consist of a series of clays and sands, very characteristic in their color, mode of occurrence, and associations, and are easily distinguished from any other beds in the Tertiary series of Texas. They include all those beds found on the Brazos, Colorado, and Rio Grande which lie between the uppermost fossiliferous strata of the marine Tertiary below and the Post-Tertiary clays, limestones, and pebble beds above. Above the uppermost of the marine Tertiary already described on the Brazos and Colorado rivers, occurs a series of clay and sandy strata, the clay rapidly becoming more and more predominant as we go up the series, until the beds are composed almost exclusively of it. Then again the sandy beds suddenly assume predominance and extend upward to the Post-Tertiary beds. The lower or clayey part of this series composes a little over half of the formation, and the sandy beds compose the rest.

These beds represent the "Grand Gulf" series of Hilgard's Mississippi section. Professor Angelo Heilprin, in speaking of the Grand Gulf Beds, says: "No unequivocal deposits of Miocene age have thus far been detected on the Gulf slope, although strong grounds exist for the supposition that the formation designated by Hilgard as Grand Gulf Group belongs to this period of geologic time, but to which division or horizon of the same it is as yet impossible to state."* In Mississippi and Louisiana, as in Texas, the base of this formation is composed of clays with lignite beds, and the upper part consists

*"Contributions to the Tertiary Geology and Paleontology of the United States," Prof. Angelo Heilprin, 1884, p. 4.

largely of sand, with calcareous seams and nodules. The local differences will be mentioned farther on. The clays vary from laminated chocolate-colored beds to massive light watery-green and pale sky-blue strata of a most characteristic and unmistakable appearance. This latter variety increases in abundance as we approach the middle of the Fayette Beds, and the clays that are associated with the upper sandy part are all of this character. They are hard, massive, heavy, with conchoidal fracture, and cut like talc. They weather a pure white. Such clays underlie the town of Rio Grande City, on the Rio Grande, and the climatic conditions here are such that they have become indurated by the heat and dryness of the region into a soft rock. Large quantities of lignite are frequently found in the clay beds, especially in the chocolate clays near the base; and even where lignite is absent, the strata are very often highly impregnated with vegetable matter, and contain the remains of many plants. The study of these will doubtless throw much light on the geological position of the Fayette Beds, but they have not yet been determined. Faulting on a small scale is of very frequent occurrence and considerable jointing is seen everywhere. Figure 2, page 52, shows a faulted lignite bed on the Colorado River, in Fayette County. Sulphur and gypsum are of very frequent occurrence, the latter often being found as twin crystals in the shape of an arrow head. The beds also frequently contain carbonate of lime in the shape of nodules, or impregnating the strata. One of the most marked characteristics of the clays, and especially of the chocolate-colored beds, is a white bleached appearance on the surface, while, a few inches in, they regain their dark color. This, and the presence of sulphur and gypsum, are intimately connected phenomena, and can be easily explained by the combined decomposition of the iron pyrites, carbonate of lime, and the vegetable coloring matter of the dark clays. The iron pyrites decomposes with the formation of sulphate of iron and sulphuric acid; the sulphuric acid attacks the carbonate of lime, forming gypsum and carbonic acid; the former is deposited as crystals, and the latter goes off in the air and surface waters. The sulphate of iron attacks the organic matter in the clays and is again reduced to iron pyrites with the evolution of sulphuretted hydrogen and oxygen. The oxygen forms carbonic acid with the vegetable matter, and rapidly goes off into the air. This reaction repeats itself until the clay finally becomes devoid of all vegetable material, and hence of coloring matter, and exposes a white surface. The sulphur, which originally formed a part of the sulphuretted hydrogen, but which has now lost its hydrogen. is deposited as a yellow or white crust on the surface and in the cracks of the strata.

The sandy strata of the Fayette Beds are very variable in thickness and consistency, though their composition is very constant. They consist almost entirely of pure coarse siliceous sand, generally sharp, and containing red

grains. It is of a gray to light buff color, and frequently contains lenticular beds of very coarse sand with grains the size of a mustard seed. These latter evidently represent eddies, or pot-holes in the surface of the bed during its deposition, as they often occur in very irregular and always in very local patches. The sand beds frequently contain lenticular seams and nodules of the same kind of watery-green clay that underlies them, and these often give the impression of being eroded masses from a clay shore line. The strata are all impregnated to a greater or less extent with carbonate of lime, sometimes occurring as a white cement in the interstices of the sand, and at others in soft white nodules, a quarter of an inch to two inches in diameter, or as lenticular beds six to twelve inches thick. The amount of carbonate of lime in these beds is much greater than that described by Hilgard* in the corresponding strata of Mississippi and Louisiana. This great increase of calcareous matter can be easily explained, as in the case of the underlying Timber Belt sands and clays, by the fact that the waters supplying the basin in which these sands were deposited were much more heavily charged with carbonate of lime than those of the other Gulf States. Of course, most, if not all, the calcareous matter that was in solution was carried far out to sea, but a large part of that in a state of mechanical suspension must have been deposited with the sands under consideration.

Rœmer,† speaking of this country, says: "You see no solid rock in place through the whole distance, excepting irregular layers of a coarse calcareous sandstone of very modern origin exposed on the steep banks of some of the rivers." The sand beds vary very much in their state of coherence. Sometimes they are soft and loose, as the sands of the modern coastal bars, but generally they are more or less hardened. The presence of carbonate of lime has much to do with this state of induration, as it acts as a cement for the sand, and frequently we find the latter in the state of a soft friable sandstone. Often, however, silica is the cementing material, and in some places we find the sand beds hardened by this substance to such an extent that they almost approach the character of a quartzite. Such beds are seen at Quarry, in the northern part of Washington County, where there are found hard siliceous and semi-transparent strata, which are very valuable for economic purposes. (See Building Stones.) Frequently the strata of the Fayette Beds form reefs across the rivers, causing rapids, and sometimes much impeding navigation. Such occurrences are seen above La Grange, on the Colorado, and in many places on the Brazos, in Washington County. Iron pyrites is

*"The Later Tertiary of the Gulf of Mexico," American Journal of Science, Vol. XXII, July, 1881.

†"A Sketch of the Geology of Texas," American Journal of Science and Arts, Second Series, Vol. II, 1846, p. 359.

of very frequent occurrence throughout these strata, and in some places the sands are stained black by the presence of oxide of manganese. Silicified wood is also of very frequent occurrence through the series, especially in the clays. Generally it is of the ordinary character of the Tertiary beds, consisting of fragments of trunks of trees, black in the interior and gray or buff color on the outside.* Sometimes, however, the silicified wood of the Fayette Beds is beautifully opalized, showing alternating layers of brown and white opal, with a bright glossy surface and a conchoidal fracture.

This whole series bears signs of a littoral deposit, and among the most characteristic evidences of this are the signs of slight erosion, followed by subsequent sedimentation. Frequently clays and sands overlie each other unconformably, but this unconformability is of only local extent, and doubtless due to changes in the currents of the waters under which the strata were deposited. Also, the presence of lumps of clay in the sandy strata tends to show an erosion of the underlying clay beds. The dip of these strata is from 0 to 5 degrees to the southeast. This trend is especially observable in the clays forming the lower part of the series, while the sands of the upper part show a greater tendency towards a horizontal dip. In this respect they resemble the Grand Gulf sands of Louisiana and other Mississippi States.

Indigenous fossil remains of fauna have nowhere been found as yet in the Fayette Beds of Texas.† In one place, two miles below the mouth of Yegua Creek, on the Brazos River, were found worn fragments of shark teeth, pieces of bone one-half to two inches in diameter, rounded fragments of silicified wood, and lumps of light watery-green clay in the cross-bedded sands of this series. These, however, prove by their worn and rounded character that they have been derived from underlying strata by the erosion of a shore line, and it is more than probable that the organic remains have been carried down into this bed, during its deposition, by the waters tributary to the Gulf as it existed at that time. A similar instance of worn fragments of fossils is to be seen eight miles below Roma, on the Rio Grande, but here also they are probably derived from older beds. There are, however, numerous remains of the flora of this epoch imbedded in the strata of the Fayette Beds. As has already been stated, the clays of the lower part of the series contain many impressions of vegetable remains in the shape of leaves, trunks of trees, etc. At one point on the Colorado, four miles above La Grange, there are found

*It may be stated here, that in this respect the silicified wood resembles that of the lava beds of Montana, Wyoming, and elsewhere in the Western States and Territories.

†Exception must be made to this rule if the beds on the Rio Grande containing *Ostrea georgiana* are included in the Fayette Beds. Exception must also be made of the vertebrate and invertebrate forms mentioned by Dr. Buckley (First Annual Report of the Geological and Agricultural Survey of Texas, pp. 64, 65).

in the sand beds many impressions of leaves very much resembling those of the palmetto which grows on many parts of the Gulf shore of to-day, together with numerous fragments of stems and trunks of the trees.*

The resemblance of these Fayette Beds to the Grand Gulf Beds of Louisiana, Mississippi, and Alabama is very remarkable. There are only two striking differences, (1) the increase of calcareous matter in the Texas beds; (2) the greater thickness of the clays at the base of the series in Texas than in the other Gulf States. The first difference has already been explained; the second is accountable, as suggested before, by the fact that as we go west from the Mississippi River the land or non-marine character of the stratigraphical equivalents of the Vicksburg Beds rapidly increases, and in the region of the Brazos and Colorado rivers very few species of the characteristic fauna of that epoch are found. Therefore it is possible that part of the clays of the Fayette Beds represent the era of the Vicksburg strata. In all other respects the Fayette Beds are identically similar to those of the Grand Gulf. They both overlie the marine strata of the region, and both occupy the stratigraphical position on the Gulf coast that is held by the Miocene and Pliocene strata of the Carolinas and other Southern States on the Atlantic coast. Both are composed of sands and clays in equally variable stages of induration, both contain impressions of land flora, and both are equally barren of all traces of animal life.

Hilgard, in speaking of this last fact, says: "I have heretofore * * * remarked that such absolute dearth of fossils in a formation whose materials are so well adapted to their preservation staggers belief, and that I interpret the calcareous seams and concretions found in some portions of the formation as derived from the long continued maceration of an apparently copious fauna, as is exemplified in the Quaternary Beds of Cote Blanche on the Louisiana coast, and notoriously in the limestone of the coral reefs."

The prairies underlaid by the Fayette Beds vary from a hilly, rolling country to a flat plain This character of topography is to be expected in a formation differing so much in its degree of induration. The soft strata tend to form the flat country, while the interbedding of alternate hard and soft beds produces a region of rolling or abrupt hills. As a rule the lower part of the formation appears to be harder than the upper, the natural result of age in such strata. Consequently, as we enter the region underlaid by the Fayette Beds we meet with hills, abrupt slopes, steep river bluffs, and a rolling country. As we go southeast—that is, towards the upper part of the formation—we come into a more gently rolling, and then a slightly undulating

*Hilgard speaks of palm wood and other vegetable remains at Bayou Pierre, Rocky Spring, and elsewhere in Mississippi. "Geology and Agriculture of the State of Mississippi," 1860, p. 149.

country; thence into the flat prairies about Sealy, San Felipe, and other places, where we finally reach the Post-Tertiary strata. Timber occurs along the streams and in inland groves throughout this region, and has already been mentioned on page 8. The sections of the Fayette Beds on the Colorado and Brazos Rivers and the Rio Grande are described below.

COLORADO RIVER SECTION.

As we enter the country underlaid by the "Fayette Beds," going down the Colorado, we pass a series of low bluffs, composed of dark gray or black clays, much jointed and faulted, until the mouth of Barton Creek is reached. Here there is a bluff over 100 feet high and composed of clay and sandy strata, as represented in the following section:

1. Red quaternary gravel and sand	12	feet.
2. Light brown sand and clay	16	feet.
3. Lenticular bed of lignite	1½	feet.
4. Chocolate colored sand and clay, with gypsum and sulphur	10	feet.
5. Lignite	1	foot.
6. Interlaminated beds of gray sand and clay of a black, chocolate or watery-green color, with gypsum and sulphur	55	feet.
7. Lignite	2 to 4	feet.
8. Similar strata to those of (6)	3	feet.

The whole formation is much faulted and jointed, and dips 2 to 5 degrees southeast. A representation of one of the jointed lignite beds is seen in Fig. 2.

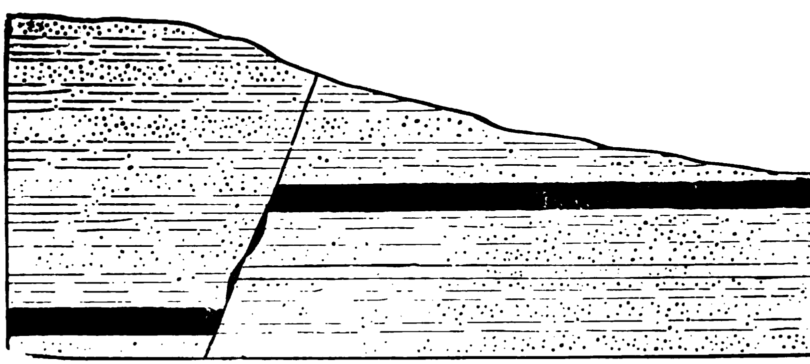

FIG. 2.—Faulted lignite bed, Barton Creek Bluff.

From here to within twelve miles, by river, of La Grange we pass over a series of outcrops of similar sand and clay strata, all dipping in the same direction, and frequently containing rusty masses of carbonate of iron. At this point we come to what is locally known as Chalk Bluff, on account of the resemblance of the hard clay to chalk. It dips 5 degrees southeast, and is 100 feet high. The following section is made up from different parts of the bluff.

1.	Pebbly quaternary drift	10 feet.
2.	Laminated chocolate clays and sandy clays, white on exposed surface, or yellow with sulphur	100 feet.
3.	Woody lignite	5 feet.
4.	Same strata as 2	5 feet.

Numbers 2 and 4 contain large quantities of sulphur, coating the exposed surfaces and joint cracks as an efflorescence. Gypsum crystals are very plentiful throughout the beds. The lignite contains masses of partly silicified and partly lignitized wood. The associated clays also contain fragments of the same material. The whole bluff presents a white or yellow appearance, but on breaking through the outside crust the sands and clays regain their original dark color. At the foot of the bluff we find fragments of a hard light watery-green clay, of the consistency of talc. These pieces came from near the top of the ledge, and will be mentioned further on. Low outcrops of the same materials are seen below this point until we come to the second "Chalk Bluff." This is about a quarter of a mile long, has a general dip of 3 degrees southeast, and is about the same height as the first one. The following section is made up from different points along the bluff:

1.	Quaternary drift.	
2.	Interbedded gray and white sand, white and watery-green clay	70 feet.
3.	Hard watery-green clay, like in (2)	4 feet.
4.	Lignite	2 feet.
5.	Similar strata to (2), light chocolate color on surface	3 feet.
6.	Lignite	1 foot.
7.	Similar strata to (5)	7 feet.
8.	Chocolate clays, with black leaf and reed impressions	½ foot.
9.	Hard watery-green clay	4 feet.
10.	Lignite	1 foot.
11.	Hard light green clay	5 feet.
12.	Similar strata to (8)	½ to 1 foot.
13.	Hard light green clay	6 feet.
14.	Lignite	1 to 2 feet.
15.	Hard light green clay	10 feet.

Leaf impressions are found in many places throughout the whole bluff, but especially in the two beds mentioned in the above section. Considerable gypsum and sulphur exist throughout the strata. The lumps of hard clay found at the base at the first Chalk Bluff are probably from a bed corresponding to the foot of this bluff. For two miles below here are seen small outcrops of similar strata, all showing a uniform southeast dip of about 5 degrees, and composed of green, grey, chocolate, and black clays or sands. In one place a lignite bed over ten feet thick was seen. The river here is very crooked, and the same beds are cut by it in several different places. Four miles, by river, above La Grange is "Palm Bluff," about 100 feet high

and covered in its lower half by a heavy bed of detritus. The upper half is composed of a series of light watery-green clay, with sand beds and calcareous seams. The upper thirty feet of this bluff is composed of sand, in places hardened into a friable sandstone similar to those already described. It is composed of sharp siliceous grains, and often contains black specks. Patches of very coarse transparent sand the size of a mustard seed and larger occur in it. Lumps of white or light brown clay and similar nodules of limestone, from one-half to one inch in diameter, are of frequent occurrence. In some places black oxide of manganese coats the grains of sand. Many impressions of a palm or palmetto leaf, as well as silicified stems and trunks, are found in the sand bed. From here to La Grange are low outcrops of the same sand as caps Palm Bluff. They are of a very striking light watery-blue color when wet, but gray when dry.

"La Grange Bluff" is about a mile below the town of La Grange. It is 100 feet high and the lower part is heavily covered by alluvium and detritus from above. The exposed part is composed of interbedded soft friable sandstones, white or yellow in color, specked in places by rusty spots of decomposed iron pyrites, and containing many small white calcareous and clay nodules. The whole bluff offers very much the same appearance as "Palm Bluff," and the sand varies from a very fine variety to that of the size of a mustard seed. Frequently a hard clay is interbedded with the sands, and when dry often weathers into nodules, due to its conchoidal fracture. The white calcareous nodules are in places so numerous that they form a conglomerate, with sand or yellow sandy clay as a matrix.

BRAZOS RIVER SECTION.

As we descend the river from the "Moseley's Ferry" shell bed, which is the uppermost fossiliferous Tertiary bed seen on the river, we reach, at a point four miles below it and at the mouth of the Little Brazos, a rapid caused by cross-bedded sands, with gray, black, and greenish clays in lenticular seams, and containing many ferruginous concretions. For over two miles below this are seen outcrops of gray sand and watery-green and chocolate clays, with lignite beds up to one and a half feet in thickness. Many calcareous concretions, one-half to two feet in diameter, are seen, as well as hardened masses of clay and sand and a tremendous amount of silicified wood in loose blocks. This wood was not seen in place, but occurred in the gravel drift overlying this formation. Nine miles below "Moseley's Ferry," and in the eastern part of Burleson County, is "Sulphur Bluff." The following section shows the occurrence of the strata:

1. Light brown hardened sandy clay	10	feet.
2. Lignite	1	foot.

3. Gray sand	1 foot.
4. Lignite	½ foot.
5. Interbedded gray sand, and chocolate and greenish clay, turned white in places on the surface	20 feet.

The whole bluff is coated with sulphur as at the "Chalk Bluffs" on the Colorado River. It is one mile long, 40 feet high, dips 3 degrees south, and presents a white and bleached appearance. Silicified wood is found in many places, and is similar to that already described on the Colorado. From here to a point eight miles above the mouth of Yegua Creek are seen small outcrops of the same sands and clays. At this point is seen a bluff showing the following section:

1. Cross-bedded gray sand, hardened in places	10 feet.
2. Hard greenish clay, with seams of chocolate clay	12 feet.
3. Lignite	1 foot.
4. Hard greenish clay	6 feet.
5. Lignite	2 feet.
6. Calcareous gray sand, with indurations	6 feet.

Dip of the strata 1 to 5 degrees south. Many imperfect leaf impressions and considerable iron pyrites are found in the clay. Three miles above Yegua Creek is seen a bluff of similar clays and sands, and a quarter of a mile below that creek, in Washington County, are seen ten feet of light green clay capped by one-half to one foot of hard gray cross-bedded sandstone. The sandstone lies unconformably on the clay, and contains lumps of the latter, proving that the increase in speed of the waters, that caused the character of the deposit to change from a clay to a sand, had also eroded part of the clay and deposited lumps of it in the sand. A mile and a half below this is a low bluff showing similar sands, composed of coarse transparent white, red, and black grains, with pebbles of the same composition, and one-eighth to one inch in diameter. There are also found in it worn pieces of silicified wood one to six inches long, with similar fragments of vitreous wood opal; lumps, singly and in lenticular patches, of light green clay, one quarter to two inches in diameter; rusty crystals of iron pyrites; worn pieces of bone, one-half to two inches long; small shark teeth, worn and broken; and small white calcareous nodules. The sand is cross-bedded, and in places hardened into a friable sandstone. The organic remains in this bed have doubtless been eroded out of the Tertiary strata and laid down here during the deposition of the sands, as they have evidently been much worn and rolled, and the shark teeth strongly resemble Tertiary forms. A mile and a half below this is a hill rising 100 feet above the river bottom, and closely resembling the La Grange bluff. It shows the same friable sandstones, coarse and fine sand, loose yellow sandy clay, with white calcareous nodules, iron pyrites, etc. From here down to the town of Washington, and thence on to where the Houston and Texas

Central Railway crosses the Brazos, in the southern part of Washington County, are seen similar strata. The sands are highly calcareous as elsewhere, and as on the Colorado frequently show a very characteristic light watery-green color when wet. Going west from the Brazos River over the "Fayette Beds" to Chappell Hill and Brenham, we travel a rolling prairie, studded with groves of elm, hackberry, and other timber, and covered with a rich black or dark red clay or loamy soil. The town of Chappell Hill is situated on a high point in this formation, and commands a beautiful view of the surrounding country. Frequent outcrops of the Fayette Beds are seen in the Houston and Texas Central Railway cuts both east and west of Brenham, and along the Gulf, Colorado and Santa Fe Railway to the north of the town. These all show the characteristic sands, soft or hardened, with or without calcareous nodules, and white or yellow calcareous clays and marls.

Friable Fayette sandstone is found in beds at Sealy at from thirty to seventy-five feet below the surface. It is overlaid by stiff massive clay, with many root impressions even at a depth of over twenty-five feet, which belongs to the Post-Tertiary strata, and will be treated farther on.

The coarse sands passed through at considerable depths in boring artesian wells at Houston and Galveston are probably of the same formation as those already described.* At these places, however, as at Sealy and elsewhere near the coast, the sands are overlaid by clay deposits, like those mentioned above. Whether these overlie the Fayette Beds unconformably, there is as yet not sufficient evidence to state definitely, but they are so different in consistency, composition, and general character that they are here treated under a separate heading. (See Coast Clays.)

RIO GRANDE SECTION.

The strata on the Rio Grande that represent the Fayette Beds are very similar in every respect to those in the region of the Brazos and Colorado. In consistency, however, they are somewhat different, but the difference is no greater than is to be expected from the different climatic conditions, and from a possibly greater content of cementing material in the shape of carbonate of lime and clay in the waters of the Rio Grande than in those of the Brazos or Colorado. The variation consists of an occasionally greater state of induration of the strata. The first undoubted beds of this series are seen five miles below the Texas town of Roma,† and in the Mexican State of Tamaulipas. They occur in a ledge three hundred yards long and one to six feet high, and consist of hard light sea-green clays with many leaf impressions

*Unfortunately, reliable records of the strata in these wells are not obtainable.

†It is possible, and even probable, that certain beds above and around Roma also belong to this series. (See p. 50.)

and rusty iron pyrites. At the lower end it is overlaid by similar beds, but somewhat harder and more sandy. Frequently small white calcareous concretions, and sometimes large clay indurations with veins of crystalline calcite, are found. Three miles below are found similar beds just above the water level, and overlaid by fifteen feet of sandstone, with concretions, fragments of worn silicified wood, and a few broken pieces of an oyster. These latter have the appearance of being derivative and not indigenous to the bed, as they are much rounded and rolled, and were very probably derived, during the deposition of the enclosing clays, from the great oyster beds of the strata about Roma. Two miles below this are seen similar beds, but with no clay, the soft and indurated layers alternating with each other. The dip is 2 degrees north 20 degrees east. This, however, is a local variation due to the causes explained on pages 16 and 45. Nine miles above Rio Grande City are seen similar sands with silicified trunks and branches of trees. The sands have the characteristic grains seen in the Fayette Beds on the Brazos and Colorado.

The town of Rio Grande City (Ringgold Barracks) is situated on a bluff of hard white clay, rising some fifty feet above the river, and indurated into a substance of a chalky consistency, though, chemically, it is only very slightly calcareous. It probably represents the light green clays of the Fayette Beds, and has become indurated by exposure to heat in a dry climate. The effect of such agencies would also account for its white appearance, as the characteristic pale green color of these clays is doubtless due to their hydration. The bed shows a highly conchoidal fracture, contains iron pyrites, and is much jointed. These joint cracks are frequently filled by veins of smoky quartz one-eighth inch to one inch thick, often showing a globular surface. The bluff extends along the river for half a mile below the town, and two hundred yards above it. Beyond these limits it disappears under the gray river silt.

Below Rio Grande City we pass through low alluvial banks for a distance of twenty-two miles. About a mile back from the river at this point, and a short distance below Las Cuevas, is a bluff of semi-hardened sharp sand, with lenticular seams of coarse sand and siliceous pebbles one-sixteenth inch to one-half inch in diameter, also white calcareous nodules one to three inches, and seams of calcareous gray clay. The bluff is fifty feet high, the upper ten feet being a quaternary conglomerate of river pebbles cemented in a white calcareous matrix. At a point ten miles above the Texas town of Hidalgo, or Edinburg, in Hidalgo County, is a low ledge rising one foot above the water and composed of Fayette sands. A similar outcrop is seen at the water edge at Reynosa, in Tamaulipas, and directly opposite Hidalgo. This outcrop reaches only two feet above the water edge, and overlying it and

forming a hill some fifty feet above the river is a hard white limestone, which will be described more fully further on.

Mr. E. T. Dumble, State Geologist, has noted the Fayette sand at the following localities not mentioned above: Beeville, Bee County; Goliad, Goliad County; Victoria, Victoria County; Cuero, De Witt County; Hallettsville, Lavaca County; Columbus, Colorado County; Wharton, Wharton County, and elsewhere.

R. H. Loughridge* has also noted the "Grand Gulf" Beds near Cuero, in De Witt County; near Oakdale, Live Oak County, and in Duval County.

Hence there is but little doubt of the continuous extension of these beds from the Sabine the Rio Grande. As already stated (p. 50) it seems probable that the beds above and below Roma, containing the large *Ostrea georgiana?*, and even certain beds up as far as the mouth of the Rio Salado and Carrizo, belong to the Fayette Series.

SOILS OF THE FAYETTE BEDS.

The country underlaid by these beds is a rolling prairie, stretching across the State from the Sabine River to the Rio Grande, parallel to the coast and from fifty to one hundred miles back from it. It borders the eastern edge of the great timber region, which also separates it from the parallel prairies of the Basal Clays and the Central Texas region. This belt is in places over sixty miles wide, and is probably sometimes over one hundred. The soil is in many parts of remarkable fertility, of a black clayey or sandy character, and heavily charged with carbonate of lime. In its local fertility this belt is in striking contrast with the corresponding region in Louisiana and Mississippi, which is often a barren sandy country, of but little agricultural value. This difference is due to the fact that the Fayette Beds in Texas, like the underlying Timber Belt Beds, are much richer in lime than in the other Gulf States, and consequently much better suited for agricultural purposes.

POST-TERTIARY DEPOSITS.

The Post-Tertiary deposits of East Texas have not as yet been thoroughly studied, and the following remarks are given simply as a preliminary statement of their occurrence. For the sake of convenience they will be treated under the following headings:

1. Upland Gravel.
2. River Silt.
3. Coast Clays.

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*"Report on the Cotton Production of the State of Texas," Tenth Census of the United States, Vol. V, p. 679.

UPLAND GRAVEL.

The Upland Gravel occurs in the shape of pebbles capping even the highest hills in the region, and is especially well represented on the summits of the high bluffs of the larger rivers. On the Brazos, Colorado, and Rio Grande it forms beds from one to fifteen feet and more in thickness. Back from the rivers, however, as far as has been seen by the writer, the gravel becomes much less plentiful, and often occurs simply as scattered pebbles, overlying the eroded surface of the Tertiary sands and clays. Hill* speaks of great beds of gravel, "Plateau Gravel," in Southwest Arkansas, which probably represent the "Orange Sands" of Hilgard. This Red River region has not been visited by the writer, but to the south of it the gravels, except nearer the larger river courses, occupy a most subordinate place in the topography of the country.

According to Hilgard, the "Orange Sands" occur in great abundance in Mississippi on the tops of the high hills and ridges, but in the part of Texas in question the hill tops are capped by soils resulting from the immediately underlying Tertiary strata, and the only representatives of the gravel are a few scattered pebbles. If we suppose the water courses at the time of the deposition of the gravel to have run in the same general direction as now, it is natural to expect a greater development of the gravel beds in the region of the Mississippi embayment than in Texas, as that river, carrying more water and having an influence over a much larger area than any Texas river, not only had a larger region to draw gravel from, but also had more power to transport it, and a larger region to spread it over. Hence the much smaller development of these deposits in Texas than in Mississippi. These pebbles in Texas decrease in size and quantity as we go down stream, and vary considerably in their composition on the different rivers. This is to be expected, as the rivers rise in the different regions, and hence their sources of supply of pebbles are different. On the Colorado they consist of limestone, flint, quartz, silicified wood, jasper, and rarely granite and feldspar. The limestone and flint have come from the Cretaceous rocks and are frequently fossiliferous. The silicified wood is rounded and worn, and has doubtless come from the Tertiary strata of the region. The other pebbles are from the area of crystalline rock in Burnet and Llano counties. The scarcity of granite and feldspar is due to the ease with which they decompose, and consequently the only representative of the granite that is usually seen is the quartz.

On the Brazos the pebbles consist of fossiliferous limestone, water worn

* R. T. Hill, Arkansas Geological Survey, Vol. II, 1888, p. 29.

Cretaceous fossils, yellow, gray, and white quartz, jasper, and chert. Here also the limestone is from the Cretaceous area, and the other pebbles from the Paleozoic area to the west of it. On the Rio Grande the pebbles are composed of limestone, flint, quartz, chalcedony, agate, black obsidian, red pitchstone, jasper, and porphyry. Many of these doubtless came from the eruptive rocks higher up the river, while the limestone and flint pebbles are from the Cretaceous area. The gravel on the high bluffs of the Texas rivers is in some places loose, and at others cemented in a ferruginous or calcareous matrix. This cemented material forms a conglomerate of various degrees of hardness. The ferruginous cement has its source in the older (Tertiary) strata of the region which underlie the gravel. The source of the iron is not necessarily in the beds immediately under the gravel, but it is invariably in the neighborhood, as it is always the case that the pebble beds in the vicinity of pyritiferous or glauconitic beds are more apt to be ferruginous than those overlying beds destitute of iron-bearing minerals. For this reason the gravel beds overlying the Tertiary strata are much more apt to be cemented than those overlying the Cretaceous, the Tertiary strata as a rule containing much more ferruginous material than the Cretaceous.

A large bed of ferruginous conglomerate is seen at "Red Bluff," on the Colorado, and in Burleson County, on the Brazos.

Pebble beds with a calcareous cement are much more numerous on the Brazos and Rio Grande than on the Colorado. This is doubtless due to the fact that the Brazos and Rio Grande flow over a vastly greater area of calcareous rocks than the Colorado, and therefore carry down much more carbonate of lime, not only in solution, but in a state of mechanical suspension. It is doubtless the carbonate of lime held in suspension that supplies the greater part of the cementing material. Such conglomerates vary from one to ten feet in thickness, and differ greatly in hardness. At Roma, on the Rio Grande, a rock of this kind is used as a building stone, and a hard compact form of it is seen capping the bluff of the river three miles below Las Cuevas. On the Brazos it is found near the mouth of Turtle Creek, McLennan County, and in many of the bluffs in Falls County.

Below these Upland Gravel beds is often found a series of lower gravel and sand covered terraces, until we reach the river bottom silts.

RIVER SILT.

The rivers of East Texas rise in various parts of the State, and hence the sediments which the comparatively swift waters of their courses carry down and deposit in the quieter basins in East Texas vary considerably in character. The Red, Brazos, and Colorado rivers rise in the eastern slopes of the "Staked Plains," in Northern Texas, pass through the red gypsiferous beds, the Pale-

ozoic rocks and the great Cretaceous area, and finally deposit, in East Texas, a sediment composed of materials from these regions in the form of a highly calcareous red sediment. The Trinity River rises in the Paleozoic rocks of Northern Texas, but far east of the "Staked Plains," and passing down through the Cretaceous area, becomes charged with calcareous matter. Hence its sediments, though often calcareous, do not have the red color of the Red, Brazos, and Colorado rivers. The Sabine rises still east of the Trinity, while the smaller rivers, such as the Neches and Angelina, rise in the timber region, and the character of the sediments of them all varies with the region they rise in and flow through.

Colorado River Silt.—The alluvium now existing in the immediate bluff of this river, and rising ten to thirty feet above the water, is composed of deep red stratified sandy and clayey silt, containing many land shells and frequent beds of leaves, as well as the branches and trunks of trees. This is frequently underlaid by gravel beds such as have been described in the high lands. Occasionally there is found overlying, unconformably, the red bluff a deposit of deep chocolate-colored stratified clay. It occurs in lenticular patches on the surface of the red bluff, and contains many beds of leaves and vegetable detritus. These deposits doubtless represent old filled-up channels or river bottom lakes. When a river shifts its course the old channel is often converted into a lake. This gradually becomes filled up by the washing of detritus by rain, by the drifting of sand by the winds, and by vegetable matter; and, after passing through the stage of a bog, eventually becomes dry land. The soft strata of the Tertiary are especially well adapted to the occurrence of such phenomena, while in hard rock they would not so readily happen. Some of these chocolate clay deposits may also represent old lakes in the course of the main river, filled up with sediment by the slackening of the waters as they enter the wide part of its channel. Occasionally both the red and chocolate bluff contain small white calcareous nodules. The alluvium now being laid down along the Colorado in the Tertiary area of Texas is a gray or buff-colored sand with occasional pebble beds.

Figures 3 and 4 show the relation of the red, the chocolate, and the gray alluvium.

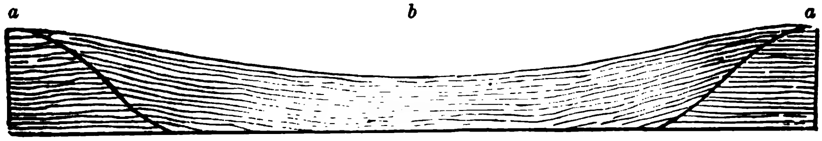

Fig. 3.—Section showing relation of red and chocolate silt. *a*, red silt; *b*, chocolate silt.

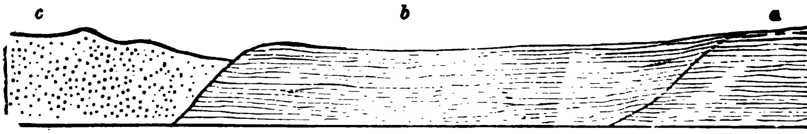

FIG. 4.—Section showing relation of red and chocolate silt and recent river sand. *a*, red silt; *b*, chocolate silt; *c*, recent river sand.

Above the river bottom are found three or more successive terraces, finally reaching the upland gravel, as explained on page 60.

The red and chocolate alluvium underlies extensive river bottom areas and gives rise to rich clay or loamy soils, varying somewhat in character with the local changes in the alluvium, but generally of a black or brown color, and very productive.

BRAZOS RIVER SILT.—The alluvium now found along the banks of the Brazos rises ten to thirty feet above the water, and is composed of stratified red and chocolate clay, often with beds of yellow, black, or light watery-green colored clay. The whole deposit is highly calcareous, and often contains many small white calcareous nodules. The yellow, black, or watery-green clay generally occupies a position below the red and chocolate, though in some cases it is underlaid by thin beds of the latter. The two deposits generally merge into one another, and in only very few cases was a sharp line of separation seen. These clays are underlaid by gravel beds one to six feet thick.

The alluvium now forming is a gray or buff sand, and in low water thin seams of clay are interstratified with it.

Above the silt deposits are a series of gravel terraces, often poorly defined, and gradually reaching the upland gravel.*

THE RIO GRANDE SILT.—The alluvium now forming the immediate bluffs of the river varies in different parts of its course. It rises from ten to thirty feet above the water, is all characterized by being highly calcareous, and containing many land shells (*Bulumulus*). From Eagle Pass to Laredo it consists of a fine gray silt, rarely showing any signs of stratification, in which respect it differs very markedly from the alluvium of the Brazos and Colorado. For some distance below Laredo it continues the same, though indistinct signs of stratification begin to appear; and from Roma on to Point Isabel, at the mouth of the river, it is markedly stratified, and often colored a light brown by iron. It frequently contains small white calcareous nodules, as on the Brazos. In the upper part of the river this alluvium is underlaid by pebble

*These terraces are much more difficult to define in the Tertiary than in the Cretaceous area, as in the former case the red-colored river deposits and the underlying older strata are of the same general color, and often of the same sandy consistency, while in the Cretaceous country the underlying chalks and clays form a radical contrast.

beds of the same material as those capping the high hills and from one to ten feet thick. These beds are not seen in the lower part of the river.

This alluvium is seen extending all the way to the coast at Brazos Santiago and Point Isabel. Here it has been eroded, and forms low hills five to twelve feet above the surrounding tide water marshes, and frequently capped with cactus and mesquite. The sides of these hills are often very abrupt and free from vegetation, clearly showing the character of the material. The alluvium now forming is likewise highly calcareous. It varies from a fine sand to an impalpable silt, so fine that clouds of dust often rise in the wind from the dry river bars.

Reynosa Limestone. — The Mexican town of Reynosa, in the State of Tamaulipas, on the Rio Grande, is situated on a hill rising some fifty feet above the level of the river and composed of a hard white limestone. This is made up of very hard calcareous nodules, one-half inch to over three inches in diameter, white to creamy-brown in color, and in places showing a concretionary structure imbedded in soft white material of the same composition. This deposit lies on the sands of the Fayette series, which are exposed at the water's edge. Though usually hard, yet in places on the surface it is soft and crumbly, and in this softer material were found many specimens of *Bulumulus alternatus*, Say., a shell found now in great quantities on the Rio Grande. These prove the late origin of at least the material in which they were imbedded, and it apparently blends into the harder rock. But unfortunately time did not permit a thorough investigation of the region, and consequently, though it is probably true that the whole of the limestone is of the same late origin, its relations and extent have not been studied. It undoubtedly overlies the Fayette Beds, as this is proved by the small outcrop of the latter at the water edge at Reynosa. Similar limestones are said to be found in various parts of Hidalgo County, and that in digging wells they are passed through for about thirty feet, when they find water in an underlying sand or sandstone (Fayette Beds?).

COAST CLAYS.

Along the coast of Texas there extends a belt of country underlaid by clays and sandy clays of a gray, yellow, or mottled color, and often black on the surface from the combination of their calcareous contents with vegetable matter. These have been seen by the writer only in a few places along the Brazos, and therefore can not be treated in full at present. They represent the Port Hudson group of Hilgard, and the country underlaid by them is a flat, open prairie, with an exceedingly rich soil. They extend inland to a distance of fifty to one hundred miles, and in some places probably more, until the Fayette Beds rise up to the surface and cut them out. The line

separating these formations is very irregular, and often long arms of coast clay run far inland, especially along the river channels, where during the deposition of the clay there were lagoons and embayments suitable for the formation of such beds. Hilgard* speaks of this formation as consisting of "a group of partly littoral and estuary, partly swamp lagoon and fluviatile deposits, whose thickness and location is manifestly dependent upon the topographical features of the continent then (during the Champlain period) in progress of slow depression, as shown by the nature of the deposits and the numerous superenclosed generations of large cypress stumps imbedded in laminated clays exhibiting the yearly fall of leaves."

Dr. Ferdinand Rœmer† says in reference to these coast deposits: "At the head of Galveston Bay, and even near the town of Houston, I found, at a height of twelve to twenty feet above the general level of the bay, large deposits of shells of *Gnathodon*, a bivalve mollusc which lives abundantly in the brackish waters along the coast of the Mexican Gulf, and in the Bay of Galveston particularly. Some few oyster shells of the common kind occur in these deposits of half fossilized *Gnathodon* shells, but there are no shells different from those now living in the bay. Everything tends to the supposition that the conditions of climate, etc., at the period when these deposits along the coasts of Texas were formed did not differ materially from the present, except that a change in the relative level of the land and sea has taken place."

COAST CLAY SOILS.

The country underlaid by this group of strata is a flat prairie, reaching from the Gulf shore to the outcrop of the Fayette Beds. The soil is a fertile black clay, very similar to that of the prairies of Western Texas. The land is now used for very little else than a great cattle range, but is doubtless destined in the future to become one of the richest agricultural regions in the Southwest, as it combines all the advantages of a most productive soil with those of a moist and temperate climate.

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*"On the Geological History of the Gulf of Mexico," American Journal of Science and Arts, Vol. II, December, 1871, p. 11.

†"Contributions to the Geology of Texas," American Journal of Science and Arts, Second Series, Vol. VI, 1848, p. 22.

ECONOMIC GEOLOGY.

THE IRON ORES OF EAST TEXAS.

The Iron Ores of East Texas all belong to the class of Brown Hematite (Limonite). Though they have been known ever since this region was originally settled by Americans, over fifty years ago, and have been and are still worked on a small scale, it has only been in the last few years that they have begun to attract the serious attention of iron manufacturers. Until then the railroad facilities were too few, and the markets too far away, to allow of the ores being utilized. But now railroads are much more numerous, and every year new lines are being pushed into hitherto inaccessible regions. Local markets in many of the towns of the State, and throughout the Southwest generally, are springing up, and the demand for pig iron is daily increasing. The population of the country is growing rapidly, and labor is becoming much more plentiful, and consequently cheaper, than ten years ago. The result of this is that iron manufacturers are now looking to Texas as a source of supply of ore for this region. These ores were worked on a small scale before, during, and shortly after the Civil War, at several small furnaces is East Texas. Most of them are now in ruins, or are rapidly approaching that condition. Among them were the Nash and Sulphur Forks furnaces, in Cass County; the well known Loo Ellen (or Kelly) furnace, in Marion County; and the Filleo and Young furnaces, in Cherokee County. Shumard,* in 1859, speaks of the Nash furnace as having been erected "several years since," and it was probably the first furnace ever in blast in the State of Texas. At present the only furnace working in the State is one of twenty-five tons capacity at the State Penitentiary, near Rusk. This produces an excellent grade of pig iron, which is largely used at the car wheel works in Marshall, Texas. Lately, however, two companies have bought up extensive tracts of iron lands, with the object of manufacturing pig iron. One of these, the Cherokee Land and Iron Company, has located furnaces at the town of New Birmingham, one and a half miles southeast of Rusk, Cherokee County. The other, the Lone Star Iron Company, is building furnaces at Jefferson, in Marion County.

The mode of occurrence and the associations of the iron ores differ considerably in the different districts, and therefore, for the sake of convenience

*First Report of Progress of the Geological and Agricultural Survey of Texas, B. F. Shumard, 1859.

in description, they have been grouped under three different headings, and will be treated separately.

1. Brown Laminated Ores.
2. Nodular or Geode Ores.
3. Conglomerate Ores.

1. BROWN LAMINATED ORES.

These ores are extensively developed south of the Sabine River, especially in the counties of Cherokee, Anderson, Smith, Rusk, and probably in Harrison, Panola, Nacogdoches, and Shelby, though this latter region has not been examined. The extension of this belt to the southwest across the Trinity River also remains to be examined.

The ore is a brown hematite of a rich chestnut color, and often of a highly resinous lustre. In structure it varies from a compact, massive variety showing no structure, to a highly laminated form, the laminæ varying from one-sixteenth inch to one-quarter inch thick, frequently separated by hollow spaces, and sometimes containing thin seams of gray clay. These often give it a buff color and a crumbly nature, and hence the name often applied to it of "Buff Crumbly Ore." The laminæ frequently show a black glossy surface, though the interior is always the characteristic rich chestnut brown color.

The table of analyses which have been made at the Survey Laboratory is given beyond. The ore occurs in a horizontal bed from one to three feet thick, and averages between eighteen inches and two feet in thickness. It is flat on top, but is bulging and mammillary below and lies at or near the summits of the highest hills in the region In fact, it is to this protecting cap of hard material that the hills owe their existence, as it has saved the underlying soft strata from the effects of erosion, which otherwise would quickly have lowered them to the level of the surrounding rolling country. The iron ore bed is directly underlaid by a deposit varying from thirty to forty feet thick of a soft yellow indurated glauconite (greensand). This bed is sometimes hardened into a soft rock, easily cut with a saw or axe, and locally used as a building stone. The interior of the bed, however, where it has not been exposed to the atmosphere, retains the dark green color of the unaltered greensand. It contains considerable iron pyrites and numerous casts of fossils of the Claiborne epoch, and represents the northeasterly extension of the Smithville Beds of the Colorado River. This bed in turn is underlaid by a great series of sands and clays, for a description of which see Timber Belt Beds. Sometimes thin seams of iron ore are found in the greensand below the main ore bed, but they are small and rarely of value. At times they lie horizontally, and at others occupy joint cracks. The main ore bed is usually directly overlaid by a thin

seam of dark brown and very hard siliceous sandstone, varying from one to six inches thick, and averaging about one and a half inches. It adheres closely to the iron ore bed, though the line of separation is sharp and well defined. Above this is a gray sandy deposit, becoming more clayey and ferruginous towards its base, and varying from one to sixty feet thick. This latter thickness is, however, very extreme, and the average is about six to eight feet. As a rule the thickness of the ore depends, in a general way, on the thickness of the overlying sand bed, it being thicker where the sand is less than fifteen or twenty feet than where it is greater. Other conditions, however, enter into the thickness and continuity of the iron ore bed, which will be mentioned under the heading of *Origin of Ores*, and which often upset the working of this rule. Nevertheless, the general fact holds good that when the ore is capped by a great thickness of sand, it is liable to be thin and discontinuous. The hills on which the ore occurs are steep and show a broad flat plateau-like surface, heavily capped with post oak, blackjack and hickory, generally of a small size, but very dense. The ore crops out on the brink of these hills, forming a protruding rim or crown, and often covering the slopes with great masses which have broken off from the main bed. These plateaus are sometimes as much as twenty square miles and more in area. They are often deeply cut by the ravines of creeks which have originated in springs in the superficial sand and which flow away from the plateau in all directions, cutting deep gullies and exposing the ore bed along their courses. On top of these plateau areas the covering of sand often conceals the ore for a distance of several miles at a time, but it is always found cropping out at the top of the slopes, and in wells, proving its continuity over very large areas. But, as has been stated above, when the overlying sands and sandy clays reach a great thickness, the ore grows thin and very often runs out altogether. Frequently there are found in the iron ore region beds of conglomerate composed of ferruginous pebbles in a matrix of sand. These are found along the rivers and creeks, and often form a prominent feature in the topography of the country. They will be treated under "Conglomerate Ores." The general distribution of the iron ores in special regions can be best understood by a detailed description of such localities, and below is given an account of the areas that have been visited:

Cherokee County.—The ore belt in this county begins at its southern end, about three miles north of the town of Alto, and runs in a northwesterly and north northwesterly direction through the county into the southern part of Smith County. Going north from Alto the ore is found capping small flat-topped hills and narrow ridges, of limited extent, until we come within five miles of New Birmingham. These ore-bearing areas show the usual brown laminated ore, but near Alto, their extreme southern limit in the county, it has not reached

its full development and continuity as seen to the north of it. The ore is thin, and the hills are scattered, small, and form isolated points, which though low in absolute elevation look high and imposing in comparison with the surrounding flat or gently undulating country. Such eminences are Collins Mountain, Taylor Mountain, Carter Mountain, and many others, varying from one hundred to one hundred and fifty feet above the surrounding drainage level, and some five to six hundred feet above the Gulf of Mexico. In this region, eight miles northwest of Alto, was situated the old Filleo furnace. It was worked during the Civil War, but abandoned immediately after that time, and it was from the immediately surrounding region that it drew its supply of ore. Five miles southeast of New Birmingham we ascend the southern extremity of the main iron range of central Cherokee County, which extends thence in an unbroken table-land, running off to the northwest for over twelve miles, and varying from one-half to three miles wide. It bears to the north and east of the towns of Rusk and New Birmingham, and finally ends abruptly at Doyle's Gap, seven miles above Rusk. Throughout this whole area the character of the ore and its associated beds is identically the same. The ore varies from one to three feet thick, is of the usual chestnut color, and is overlaid by from three to ten feet of gray sand. The new town of New Birmingham is built on the western slope of this range at a distance of one and a half miles southeast of Rusk, the county seat of Cherokee County, and is the location of the furnaces of the Cherokee Land and Iron Company.

Doyle's Gap is a narrow break, half a mile wide, in the main range, and to to the west of it we again ascend the northeast corner of a similar iron-bearing plateau. This is the eastern part of what is known as the Gent Mountain country, which extends hence in a southwesterly direction to within eight miles of the Neches River. Going west from Rusk we strike the southern part of the Gent Mountain range in six miles, and in about four miles further reach the village of Gent, situated on the southwestern corner of the plateau. This range is almost cut in two by Horse Pen and One Arm creeks, running respectively north and south from the summit, but the two parts are connected by a narrow neck of ore-bearing land. This area is some six miles long by four to five miles wide and is almost continuously underlaid by iron ore. From the summit of Gent Mountain can be seen the sloping country to the west, running to the swampy bottom of the Neches, some eight miles distant. Beyond the river the country can be seen gradually rising into the forest-clad hills of Anderson County. To the south the low, flat, or undulating country forming the Neches and Gum Creek bottoms spreads out in rich pine and gum tree thickets. To the east and north are seen the ore-bearing highlands of central Cherokee County, covered with a thick growth of hickory, blackjack, and post oak, and extending on the east beyond Rusk,

and on the north to within five miles of Jacksonville. Gent Mountain is some three hundred feet above the Neches River. For the first two hundred feet the slope is very rapid and then drops more gradually to the river.

The following section on the slope of the plateau and just east of Gent shows the occurrence of the ore:

1. Gray or buff colored sand	1 to 10 feet.
2. Siliceous sandstone capping	1 to 2 in.
3. Brown laminated iron ore	2 feet.
4. Indurated greensand with thin seams of clay and casts of fossils	45 feet.
5. Coarse white clayey sand	20 feet.
6. Dark blackish-brown sand, more clayey towards the base, nodules of rusty clay ironstone showing shrinkage cracks	31 feet.
7. Brownish-gray sand to base of section	11 feet.

To the west and northwest the Gent Mountain range is bounded by Gum Creek, and beyond it the iron-bearing plateau again becomes broken up into numerous flat topped hills and narrow ridges, extending from Gum Creek to the International and Great Northern Railroad, and beyond. The railroad takes advantage of this break in the main range to pass through the plateau country, and it is the only east and west pass in a distance of over twenty-five miles. Among the most prominent of these isolated hills are Iron-Furnace Mountain (the location of the old Young furnace), Gray's Mountain and Grimes Mountain. Beyond we come to another iron-bearing plateau. It begins in its southern extremity at Ragsdale Mountain, three miles west of Jacksonville, and extends on the north to the old town of Larissa, where again it is cut off by Killough Creek. This range is over six miles long, and three miles wide in its widest part. On the east side it slopes off in a series of fertile red and mulatto soils into Gum Creek bottom, which separates it from the Mount Selman range. On the west slope of the plateau is a broad fertile agricultural country, with soils similar to those on the eastern slope, and reaching to the Neches River, a distance of five to eight miles. The ore is of the same general character as that already described. It varies from one to three feet thick, is capped with the usual one to three inches of hard brown sandstone, and one to six feet of gray sand. The prosperous town of Jacksonville is beautifully situated three miles east of Ragsdale Mountain, and on the southwestern slope of the Mount Selman range. The International and Great Northern Railroad enters the town from the southern end of the range, and the Kansas and Gulf Short Line comes down the southwestern slope, intersecting the International and Great Northern at Jacksonville. Going northeast from the town, the summit of the plateau is reached in about one and a half miles. The ore shows itself in the gullies and breaks of the mountain slope, and is of the same character and thickness as that described

on Gent Mountain and elsewhere. The range is of the customary plateau character, is twelve miles long, and varies in width from a hundred yards to a half mile. The sand cap overlying the iron here is much thinner than on many of the other iron-bearing ranges, and often the bare ore bed is exposed directly on the surface of the ground, thus adding greatly to the value of the deposit, as the mining of it requires but little or no stripping. The absence of this covering is doubtless due to the narrowness of the range, which has made it easy work for the surface waters to wash away the loose sand, and also to a westerly dip of the iron ore, which has still farther facilitated the erosion of the surface deposits, by allowing the superficial waters to run off at a rapid rate, and all in one direction. This westerly dip is peculiar to this plateau, and extends along it throughout its whole length. It is doubtless due to a local sinking to the west of the underlying strata, probably before the formation of the iron ore, and also before the plateau was cut out of the Tertiary strata. At Mount Selman, eight miles north of Jacksonville, the ore on the eastern brink of the range is seventy feet higher than it is on the western side, less than one mile distant. Another result of this dip is to make the eastern slope of the range very steep, and in some places perpendicular, while the western slope drops off much more gradually toward Gum Creek bottom. Mount Selman is simply a part of this range, and the village of that name is situated directly on the summit of the plateau. To the north of it the ore extends for four miles, and reaches its terminus at a point one mile south of the Smith County line, and a little greater distance southeast of the village of Bullard. Here the range ends in a small flat-topped hill a hundred yards long by ten to thirty yards wide. To the north from here the country slopes off gradually to Tyler, in Smith County, in a stretch of fertile country with red and mulatto soils, and largely underlaid by glauconiferous strata. The Kansas and Gulf Short Line follows the crest of this ridge from below Bullard to within three miles of Jacksonville. In a cut on this road about a mile and a half south of Mount Selman is seen a somewhat unusual occurrence of iron ore. It consists of large concretionary masses six to seven feet in diameter, of a black or dark rusty-brown color, and imbedded in the indurated altered greensand. This is overlaid by the regular horizontal bed of ore, as shown in Fig. 5, Plate II.

The origin of these masses will be explained on page 73. A short distance south of this is McKee's Gap, which is a narrow break in the top of the plateau and is the only interruption in the continuity of the iron ore throughout its whole twelve miles of extent. The ore of this area is of very regular thickness, varying from two to three feet. The following section on the eastern slope of the range south of Mount Selman shows the occurrence of the ore:

1. Gray sand	0 to 2 feet.
2. Brown laminated ore	2 to 3 feet.
3. Indurated greensand	30 feet.
4. Detritus.	

This region forms the divide between the waters of the Neches River on the west and Mud Creek, the headwaters of the Angelina River, on the east. It reaches its highest elevation at Mount Selman, where it is seven hundred feet above the sea. From here north to the limit of the iron ore there is but little change in height, but from there to Tyler it drops off to 531 feet. To the south of Mount Selman the plateau maintains almost the same elevation to within a mile northeast of Jacksonville, when it rapidly slopes off to 525 feet at that town. From the summit of the ridge the land slopes off on the east very abruptly for a hundred feet, and sometimes shows two or three successive benches (see pages 84, 85); thence the grade is more gradual down to the settlement of Little Arkansas and to Mud Creek bottom. To the west the grade slopes off in gently undulating hills, with a rich growth of pine, oak, and hickory, and watered by numerous creeks and springs.

The town of Lone Star, in Cherokee County, is situated about ten miles south of the Smith County line, and near the line between Cherokee and Rusk counties. To the east of the town is seen a series of ore-capped hills, one of them two miles long by a quarter of a mile wide. The ore is one to two feet thick and is often discontinuous under the heavy covering of gray sand.

Smith County.—The continuation of the same iron ore belt as is seen in Cherokee County is also found in the southwestern part of Smith County. It caps ridges varying from one-quarter to three miles long, and is also found on isolated flat-topped hills. It is of the brown laminated variety, and occurs in the same associations as in Cherokee County. Eight miles southeast of Tyler, on the land of Col. W. S. Herndon, of Tyler, the ore was seen in large quantities. It is laminated, dark or light brown, with a bright black gloss on the laminæ. Sometimes it is of a buff color and crumbly. On the slopes of the hills are seen the characteristic ore-capped benches, which here are two in number. Between here and Tyler are several other small outcrops, in the William T. Wright and James Kelly surveys. In the northern part of the county are also considerable areas of iron ore. These have not been visited by the writer, but have been partially traced out by Mr. G. E. Ladd. They extend in broken areas from three miles west of the Missouri, Kansas and Texas Railroad, in a westerly direction to the Van Zandt County line, and at a distance of two to six miles south of the Sabine River.

Anderson County.—The iron ore of Anderson County is identical in every respect to that of Cherokee, not only in its general character, but in its mode of occurrence and its origin. In fact, it is simply the westerly contin-

uation of the same belt as has been described in that county. Going north from Palestine, the county seat of Anderson County, the main iron-bearing range is met at about three miles from the town, and extends in a great plateau, often broken up into separate flat-topped hills, from here northerly towards Beaver, Brushy Creek, Kickapoo, and the Henderson County line. To the east this plateau breaks into small hills extending to the Neches River, and to the west it gradually disappears in the same way in the water shed of the Trinity River. This iron region forms the divide between the Neches and Trinity, just as in Cherokee the Selman Range forms the divide between the waters of the Angelina and the Neches. In this range, as in Cherokee, springs give rise to many creeks, which flow down the steep slopes of the plateau, come together in the lowlands, and finally discharge into the muddy waters of the main rivers. The ore found here is continuous over large areas, and maintains a very steady thickness of one to three feet. To the south of Palestine the same ore is found, but here the bed is generally thinner and less continuous and the ore bearing hills are more scattered, though the ore is of very good quality. Many of the hills are capped with hard, yellow altered greensand, but carry no ore. The iron range in the great highland region to the north of Palestine comprises most of the ore of the county, and is of very great economic importance. What adds still more to its value is its nearness to the pure white limestone in the Saline, six miles southwest of Palestine. This is excellently adapted for a flux in smelting iron ore, and in consideration of the rarity of such deposits in East Texas, is of the greatest practical importance.

HENDERSON, VAN ZANDT, RUSK, NACOGDOCHES, PANOLA AND OTHER COUNTIES.—Iron ore also occurs in the southeastern part of Henderson County, and in Van Zandt, Rusk, Nacogdoches, Panola, and elsewhere in this region, but only a few spots in these counties have as yet been visited by the writer. In Henderson County, on the Cotton Belt Railroad and one mile east of Athens, are seen thin seams of a brown hematite ore, two to twelve inches thick, and associated with sands and clays. This bed belongs to the class of nodular ores, which will be described later on. In the southwest part of the county ore is also found, but it has not yet been seen by the writer. In Rusk County brown laminated ore is reported to exist in large quantities.

ORIGIN OF THE BROWN LAMINATED ORES.

These ores are always associated with the glauconite deposits. Though they are sometimes separated from it by a thin bed of gray clay, they invariably overlie it very closely, and where the glauconite disappears, so also the iron ore disappears. On the other hand, however, the same glauconiferous stratum

is frequently found without any covering of ore. A comparison of the parts of the bed that carry ore and the parts that do not, discloses the following facts: That the parts carrying ore are yellow, indurated, and partially decomposed for some distance in from the surface; also that though they once contained large quantities of fossil shells, these shells have either entirely or almost entirely disappeared and only the casts of the shells remain; also that when the bed is dug into until the green undecomposed part is reached, large qauntities of undecomposed iron pyrites are seen, the only trace of it on the outside being rusty spots or a hard brown ferruginous crust; also in the sandy clay immediately overlying the greensand there are frequently found large quantities of iron pyrites. An examination of the part that does not contain ore, or where the ore is very thin or scattered, discloses the following facts: The greensand preserves its green color often even on the surface, and shows little or none of the tendency to go into a yellow mass seen in the iron regions; also the fossils are represented by the shells themselves, and not by the casts of the same; also little or no iron pyrites is present. The natural conclusion from these facts is that the presence of iron, the removal of shells, the alteration of glauconite, and the accompaniment of iron pyrites are closely connected phenomena; and everything goes to show that they are not only closely connected, but are absolutely dependent on each other. The explanation seems to be that the change results from the decomposition of iron pyrites. The decomposition of this mineral gives rise to sulphate of iron and sulphuric acid. The sulphate of iron is either carried off in surface waters or decomposed on the spot into hydrous peroxide, the basis of the iron ore of the region. The sulphuric acid, set free by the decomposition of the pyrites, attacks the fossil shells, which are composed largely of carbornate of lime, and forms carbonic acid and sulphate of lime (gypsum). It also attacks the glauconite, decomposing it either partially or wholly, and converts it into the yellow indurated mass seen everywhere in the iron ore region. In many places, however, iron pyrites has not produced the whole of the iron ore bed, but has been assisted by the decomposition of the glauconite, which itself contains over twenty per cent of metallic iron. When the pyrites is absent this does not decompose easily, but the continued action on it of sulphuric acid, from the decomposition of the pyrites, causes it gradually to break up into its various constituents. The sulphate of iron resulting from this would, in turn, become decomposed into the hydrous peroxide, which would be deposited with the portion of the same material furnished by the iron pyrites. That the ore is often entirely produced by the pyrites unassisted by the glauconite is proved by the fact that it is often separated from this latter by a clay one to three feet thick; and that the glauconite does sometimes assist is seen in the occasional blending of it with the ore, as well as in the very rare occur-

rence of glauconite fossil impressions in the iron ore. A large supply of iron pyrites is also found in a thin bed of sand and clay containing large quantities of, and often entirely composed of, that mineral, with small pieces and seams of lignite, and directly overlying the glauconite. The following section shows its occurrence in a pit at McBee School, two miles east of Alto, Cherokee County:

1.	White sandy clay...............	10 to 30 feet.
2.	Ferruginous sandy clay becoming stony hard at the base	1 foot.
3.	White siliceous sandstone with a cement of finely disseminated iron pyrites..	1 to 3 in.
4.	Loose sand with lenticular masses of lignite, one to four inches thick, and many disseminated particles of iron pyrites, running into a very plastic dark greenish-brown clay below............	3 feet.
5.	Dark green glauconitic marl with casts of fossils, at bottom of the pit.	

Here we doubtless have the original condition of the strata above and below the iron ore horizon before the brown hematite was formed. It will be seen that the brown hematite is not represented in the section, but in its place, i. e., below the top of the sandy clay and above the greensand, are some four feet of clay and sand, with large quantities of iron pyrites. There is enough of this mineral here to give rise to a bed of brown hematite ore equal in thickness to the average of that found in the country, without the assistant supply from the glauconite. The ferruginous matter from the decomposition of the pyrites would percolate into the black clay and with it form the brown hematite as it now occurs. The clay would supply alumina to the ore, and hence the source of that material found in all analyses. Also, the ore frequently contains inclusions of clay, and the laminæ are often coated with a thin film of it, giving rise to a brittle gray colored mass known as "buff-crumbly ore." In fact every material found in the brown hematite is also found in the materials of this section, and the process of decomposition and of subsequent reconstruction in an entirely different form of the substances involved, is simply the fulfilment of the laws of chemistry. The reason that this section is still seen in this almost entirely unchanged state is due to the fact that the overlying sandy clay is a very stiff impervious bed, and has protected the underlying strata from the decomposing influences of the air. But that even in spite of this protection it is beginning to decompose, is seen by the ferruginous crust at the base of 2 in the section. Also by the fact that a spring, heavily charged with iron, rises from it. This fact also gives a reason for the local absence of the ore, even in the iron ore belt, where the capping of sand is very heavy or very clayey, as this protects the iron pyrites from decomposition, and hence prevents the formation of the brown hematite. Another cause for this absence of the hematite is also to be found in the very probable local absence of the pyrites, even in the midst of pyrit-

iferous strata. It is only natural that iron pyrites, dependent as it is on the combined decomposition of organic matter and soluble salts of iron, should be somewhat uncertain in its presence, and it is a most remarkable fact that it should be so regularly distributed as it is found to be in the iron ore region. The McBee School section also explains one of the most perplexing occurrences in connection with the iron ore region, and that is the capping of dark brown hard, flinty, and siliceous sandstone, directly overlying the ore and from one to six inches thick. This rock is sharply defined from the ore, and often contains fragments of ferruginized lignite.* Such a deposit could easily be formed from the constituents of beds 2 and 3 by the decomposition of the pyrites, first into sulphate of iron and then into the hydrous peroxide, and the subsequent cementing of the sand by this latter material. The McBee School section is the only one of the kind that has been seen by the writer. But this rarity of such occurrences is very easily explained, as they can exist only when protected by either a heavy covering or an impervious one, and hence are usually obscured. The exposal to view of the case in question is an accidental occurrence, due to the cutting of a steep ravine, and the fact that the overlying sandy clay was so dense and impervious that a thin cover of it protected the underlying strata. A fact, however, that tends to prove its existence elsewhere is the almost universal occurrence at the contact of the glauconite and overlying sandy clay of highly ferruginous springs, especially in places where no brown hematite is seen. The exact contact is invisible, as the sandy clay has invariably drifted over and obscured it. The shape of the ore bed is also strong proof that these chemical and physical actions have gone on; the upper surface of the bed is usually flat, but the base of it is very uneven and shows a bulging mammillary form and large concentric bulbs at the bottom. Frequently the bulging parts of the bed are in separate masses, though they are closely compacted together like a paved road. A yellow clay lies directly under the ore, often resulting from the decomposition of the glauconite. The upper surface of some of these masses is distinctly concave, while the lower is still more convex. This evidently tends to show that it was formed somewhat in the manner of a stalactite, by a downward movement of the iron bearing solutions. The interior of the ore contains inclusions of a very plastic gray clay, giving it a buff color. Sometimes the base of the ore bed is very uneven, and shows the very irregular shape of the bed deposited by the percolation of soluble salts of iron.

Frequently minor seams, beds, and concretionary masses of iron ore are

* The chemical reactions by which this lignite became ferruginized are somewhat uncertain, yet the fact that the material was once lignite or wood is proved by its structure. Hilgard speaks of similar occurrences in the Quaternary deposits of Mississippi. (Agriculture and Geology of Mississippi, 1860.)

found in the interior of the glauconite bed, and the principle of their formation is doubtless similar to that already described, by the decomposition of iron pyrites, often assisted by glauconite.

2. NODULAR OR GEODE ORES.

These ores, though somewhat similar in chemical composition, are distinctly different in physical character and in their mode of occurrence from those already described. They are well developed in the northern part of Marion County and in southern Cass County, and extend thence into Morris, Camp, Upshur, and the counties lying to the west.

The ore is a brown hematite and occurs in a great variety of forms. It very rarely shows the laminated structure of the brown laminated ores or their resinous lustre. It generally occurs as nodules or geodes, or as honeycombed, botryoidal, stalactitic, and mammillary masses. It is rusty brown, yellow, dull red, or even black in color, and has a glossy, dull, or earthy lustre. The most characteristic feature of the ore is the nodular or geode form in which it occurs. Some of the beds are made up of these masses, either loose in a sandy clay matrix or solidified in a bed by a ferruginous cement. The ore lies horizontally at or near the tops of the hills, in the same manner as the brown laminated ores to the south of the Sabine River. The beds vary in thickness from less than one foot to over ten feet, the thicker ones being often interbedded with thin seams of sand. The ore-bearing beds are immediately overlaid by sandy or sandy clayey strata. The sand beds are in the majority, though pure clay is found at some distance below the ore. The overlying sands are at times entirely eroded and the solid floor of brown hematite is exposed to view. In other places it is covered by from one to thirty feet or more of sand. This overlying stratum varies considerably in character; sometimes the sands are loose and gray, at others more or less solidified and deeply stained by iron. Sometimes they contain considerable clay and show ferruginous segregations, so that a section of the bed discloses lumps of hard, yellow semi-hardened sandy clay. The beds also often have a mottled red, yellow, and white appearance, and contain thin seams and lumps of clay. The sands are very much cross-bedded, and frequently layers of hard-pan or thin ore are seen following the lines of cross-bedding. Unlike the ores of Cherokee, these beds are not dependent on the thickness of the immediately overlying sands.

Sometimes, though not so often as in Cherokee County, the ore is capped by a stratum of hard ferruginous sandstone* varying from one inch to over a foot in thickness, and occasionally similar beds are interstratified with the

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*Frequently this sandstone is found alone and without any ore. In such cases it sometimes reaches a thickness of over twenty feet. (See Building Stones.)

ore. The line of separation of the top sandstone and the ore bed is sharp and well defined. Though the iron ore is usually found near the tops of the hills, one or more beds are often seen at a lower level, lying horizontally like the upper bed, and separated from it by sands. These lower beds, unlike those in Cherokee, are often just as thick or thicker than the top beds. Such a formation as this, with its interstratification of soft and hard beds, gives a very characteristic topography to the country. As in the Cherokee region, the horizontal strata have been cut through by the numerous rivers and creeks, leaving flat-topped hills and plateaus, with steep escarpments and an alternately receding and protruding outline, resembling, on an exceedingly small scale, the sides of the western canyon.

The beds of the creeks are generally very sandy from the detritus washed down from the uplands, and frequently large beds of conglomerate, composed of ferruginous pebbles in a sandy cement, have been formed along the stream.

In many places benches are seen along the slopes of the hills. These, unlike those in the land of the brown laminated ore, probably owe their origin to the alternation of hard and soft beds, as has been explained on page 24.

MARION COUNTY.—The largest beds of ore in this county lie to the north and northwest of Jefferson. Six miles northwest of the town is the old Kelly (Loo Ellen) furnace, which formerly drew its supply of ore from the surrounding country, but which has now been deserted. Going northwest along the Missouri, Kansas and Texas Railroad, the ore is seen in large quantities near Lasater station. At Leverett's Hill, a half mile from the station, the following section was seen:

1. Nodular ore, brown or yellow on the outside, black and glossy on the inside, kidney shaped and rounded, 1 to 24 inches in diameter, mixed in brown sandy clay...	2 feet.
2. Solid bed of brown, yellow, and black limonite ore (brown hematite)...	2 feet.
3. Ferruginous sand to base of hill... ..	10 feet.

Large quantities of this nodular ore are said to have been used at the Loo Ellen furnace, nine miles south of here, and a pile of several hundred tons of it is still to be seen there. The nodules or geodes are generally hollow, though sometimes they contain a coating of red ochre on the inside, which has been locally used for polishing metals. At the base of the hill in the bed of a dry creek is seen a deposit of conglomerate ore. (See Conglomerate Ores.)

Two miles east of Lasater Station is Lasater Hill, where there is a deposit of ore of a yellowish-brown color, in places over ten feet thick, and overlaid by sand beds carrying a thinner layer of ore. The following section shows its occurrence:

1. Buff colored sand	1 to 15 feet.
2. Brown rusty ore	$\frac{1}{2}$ to 1 foot.
3. Yellow and buff sand	20 feet.
4. Main ore bed	10 feet.

Johnson's Hill is about three miles north of Lasater Station, and forms part of the divide between the waters of the Big Cypress and the Black Cypress rivers. It is about three miles long from north northeast to south southwest, and a mile wide. It looms up as a flat-topped plateau, and its surface is capped with masses of ore broken from the underlying bed. The capping of sand is here often entirely absent, a fact that is most important in facilitating the mining of the ore. A section of the ore bed on this hill shows the following strata:

1. Ore bed, stratified and in geodes, brown and black, bed much broken, interbedded with seams of sand	4 to 10 feet.
2. Ferruginous and mottled clays	3 feet.
3. Ore, similar to the stratified part of 1	$\frac{1}{4}$ to $\frac{1}{2}$ foot.
4. Interbedded ferruginous sands and clays	20 feet.
5. Mottled red and white sandy clays	10 feet.
6. Red ferruginous sandy clays	65 feet.

Continuing northwest into the southwest part of Cass County, we come to Barnes' Hill, six miles northwest of Johnson's Hill, and three miles from Avinger, a station on the Missouri, Kansas and Texas Railroad. Here ore is found in very large quantities, and directly on the hill top. Large loose masses cover the surface as on Johnson's Hill, often in such quantities as to impede travel.

To the north of this is situated the old Nash furnace, built before the Civil War, but now abandoned.

Berry Hill is seven miles north of Jefferson. It is a broad plateau, comprising some four thousand acres, a large part of which is underlaid by iron ore. The following section shows the general mode of occurrence of the ore:

1. Red sandy clay, with seams of hard-pan, and rounded ore pebbles $\frac{1}{4}$ to 2 inches in diameter	2 feet.
2. Mottled sandy clay, with same pebbles as 1	5 feet.
3. Interbedded seams of iron ore and hard-pan	15 feet.
4. Mottled red and white sandy clay	10 feet.

Bed No. 4 runs to the foot of the hill and becomes covered by drift sand in the bottom of a creek, so that only ten feet of it can be seen. The iron ore in the above section is a brittle, stratified brown hematite. On a hill to the north of this exposure was seen a bed of conglomerate ore from one to two feet thick. Going east from here, similar ores are seen near Linden, Atlanta, Springdale, and other places. Near Springdale is a high hill, rising 512 feet

above the sea level. The top of the hill is covered by a stratum of compact iron ore and ferruginous sandstone, about two feet in the thickest part seen. The ore appears to be sometimes interstratified with the sandstone, and at others to be segregated in it. On this property was located the old Sulphur Forks furnace, which was worked during the Civil War. Similar deposits are to be found in many places in Marion and Cass counties. The ore is generally associated with mottled clays, and interstratified clays and sands, and the thick bed of red sandy clays shown in the Johnson Hill section. Occasionally, as between Kilgore and Atlanta, the ore is underlaid by a pure white sand, associated with the other beds mentioned above. Underlying the sands and clays of the iron bearing formation, is a bluish-gray clay, sometimes sandy. In this bed clay ironstones have been found in digging wells. They are of a light gray color inside and brown from oxidation on the outside. Going west from Marion and Cass counties, similar iron ore is found in the adjoining country. In Van Zandt County the ore thins out, and entirely disappears in its western limits.

ORIGIN OF THE NODULAR OR GEODE ORES.

These ores, as has been stated, are all associated with sands and clays in horizontal or almost horizontal beds, and apparently conformable with the underlying and overlying strata. The existence of these ores, often between two non-ferruginous strata, would seem to preclude the possibility of their origin from external sources, and consequently it is necessary either to account for their presence from a local source or to suppose them originally deposited with the associated strata in the same form as they are found now. This latter supposition is not probable, as the structure of the bed is not such as would be expected in such a deposit, nor does the ore partake of the nature of a bog deposit. There is very little iron pyrites or glauconite present, and consequently they can not have participated in its formation, as in Cherokee County. There are, however, large quantities of clay ironstone nodules in the unexposed strata below the ore bed, and they are frequently found in digging wells. They are composed of carbonates of iron and lime, with alumina, silica, and other ingredients in smaller proportions, and there is strong evidence that the brown hematite is the result of the decomposition, in place, of such nodules. They are rarely in a continuous bed, but usually in flat lens-shaped masses, one to six inches thick and one-half to three feet long, and often laid in horizontal beds very close to each other. These nodules are in their undecomposed state of a gray color, very hard and heavy, and often show shrinkage cracks in the interior. They are generally, however, partly decomposed into peroxide, and have a hard brown rusty crust, weathering off in concentric layers, and varying in thickness with

the amount of exposure to the atmosphere. Eventually the whole mass decomposes, and the whole of the carbonate of iron is converted into peroxide, and as a result we have the brown hematite nodules and geodes of the present iron ore beds. It doubtless occurred in some places, that as the clay ironstone gradually decomposed, a part of the resulting peroxide was taken up by carbonated waters and redeposited again whenever the water was exposed to a sufficient extent to lose its carbonic acid. This action would cement the nodules and geodes, and form the continuous stratified beds which we often find in the iron ore region. Where such action has not gone on we have the loose nodules, such as are seen at Leverett's Hill. An analysis of this clay ironstone from Van Zandt County gives the following ingredients:

Oxide of Iron (equals Metallic Iron 31.71)	45.30
Alumina	17.04
Lime	15.68
Silica	6.91
Carbonic Acid	12.32
	97.25

Here is a source of supply for all the constituents of the brown hematite. In the chemical changes that have gone on some of the original constituents have been partly lost and the percentage of others proportionally increased. The carbonic acid was originally combined with the iron and lime. That part of it associated with the iron has been entirely removed, and was probably the source of supply for the carbonated waters which dissolved and redeposited part of the peroxide of iron, as explained above. The lime, combined with its portion of carbonic acid in the form of carbonate of lime, has been carried away in solution, thus removing the last of the carbonic acid. Consequently the percentage* of iron in the bed is increased directly as the accompanying constituents decrease, and the result is that from a clay ironstone containing little more than thirty per cent of iron we now have the brown hematite with a composition as shown in the analyses and an iron contents of forty to fifty per cent.

One of the strongest proofs of this mode of formation of the iron ores is the fact that above the water level of the region, where the strata have been exposed to all the oxidizing influences of the air, the iron ore is all, or most all, in the form of brown hematite, while below the water level it is in the form of clay ironstone, to whatever depth we go. Now, as the strata lie almost horizontally, these two forms of ore, lying as they do one far above the other, must occupy different horizons, and consequently it might be said

*Of course in this process of breaking up of the clay ironstone, some of the iron is lost also, but the amount carried away in this manner is very small.

that this difference in character of the ores was due to the different modes of formation during the deposition of the respective strata. But these strata are so very similar, both in chemical composition and physical character, that it does not seem possible that the ore in them could be so absolutely different. Also, as we approach the water level going down through the strata, the brown hematite does not run abruptly into the pure clay ironstone, but we come to intermediate beds composed of ironstone partly decomposed and covered with a crust of hematite. Still lower down the crust becomes thinner, until finally the pure clay ironstone is found. It must be admitted that, as far as the writer's experience goes, no beds of clay ironstone of sufficient size to produce some of the thick beds of brown hematite in the Marion and Cass county region have been seen. But this can be accounted for by the fact that the clay ironstone, on account of the underground position it occupies, is rarely seen, and data concerning it are only gotten in wells and a few river bluffs. Hence its greatest thickness is still in obscurity.

3. CONGLOMERATE ORES.

The variety of ore included under this head consists of a conglomerate of brown ferruginous pebbles one-quarter to two inches in diameter and cemented in a sandy matrix. Sometimes a few siliceous pebbles are also found. The beds vary from one to twenty feet thick, and are generally local deposits along the banks and bluffs and sometimes in the beds of almost all the creeks and streams in the iron ore regions just described. Sometimes they cap the lower hills. They are generally of low grade, but could be concentrated by crushing and washing out the sandy matrix. They usually contain more or less ferruginous sandstone in lenticular deposits, and are much cross-bedded. These ores are seen throughout East Texas from the Red River to the Brazos, but have as yet been put to no practical use, on account of the abundance of the other ores. On White Oak Creek, in the same county, and at the house of William Smith, a bed of this rock is seen which in places is twenty feet thick, and interbedded with sandstone. It rises from the bed of the creek upwards, and is traceable at intervals for several miles above and below this place. Similar beds are seen on the Neches and Angelina rivers in many places, as well as on Larisson, Bowles, Box, Gum, Killough, Mud, Sulphur, and other creeks in the same county. Such beds are also found in Anderson, Smith, Rusk, and the surrounding counties. In Marion and Cass counties they are also plentiful. Near Lasater, Marion County, conglomerate ore is found at the foot of Leverett's Hill, and also in the streams running off of Berry Hill.

This variety of ore has generally originated by the cementing together of

ferruginous pebbles and nodules in the beds of the streams. The pebbles have originated both by the breaking up of iron ore beds, and by the collection of ferruginous concretions in the destruction of sand and clay beds. The first class of pebbles do not necessarily all come from the large ore beds already described, though many of them doubtless are derived from that source, but a large quantity also come from the breaking up of thin seams of hard-pan and iron ore often less than an inch thick. These are of universal occurrence throughout the iron ore region, and readily succumb to the denuding action of the atmosphere. They break into fragments, become rolled and rounded in the creek beds, and are finally deposited in a solid stratum. The second class of pebbles, i. e., those from the sand and clay beds, are nodules resulting from the oxidization of iron pyrites and from the segregation of ferruginous solutions. When the sand or clay beds containing these are eroded, the pebbles are carried down into the streams and mixed with others just described. These iron ore fragments and nodules collect in very large quantities, especially in the creek beds, where the water has in many places carried away much of the lighter sand and concentrated the pebbles. The ferruginous matter in the sandy matrix of this rock owes its source to the solution of iron salts in the streams and springs throughout the region. These solutions run over and percolate into the originally loose bed of ore pebbles, become rapidly oxidized, and deposit red peroxide of iron, which, acting as a cement, binds the whole mass together. This action can be seen going on in many places at the present time, and is only the natural result of the physical and chemical influences now at work in the East Texas region.*

Though this is the usual mode of formation of these beds, there are some that have evidently originated differently. These have the appearance of a mass of small nodules, one-eighth to one-quarter inch in diameter, in a porous mass, with cavities between the separate nodules, and with little or no sand. Such deposits are probably formed by the partial erosion in place of sandy beds containing ferruginous nodules. The sand, being lighter than the ore, is carried away by the surface waters, while the nodules remain and become solidified in a porous bed. Some of these nodules, of course, are carried down into the streams, and go into the form of conglomerate just described, but many of them doubtless remain.

These ores are much richer in iron than the other variety of conglomerate ores, and sometimes analyze over forty per cent of that metal.

*These ores are of low grade and of little economic value.

ANALYSES OF IRON ORES FROM EAST TEXAS.

1. Limonite, from Athens, Henderson County. Contains no phosphorous, sulphur, manganese, or titanium.
2. Limonite, from Fosterville, Anderson County.
3. Limonite, from 1¼ miles S. E. of Brownsboro, Henderson County.
4. Limonite, from 7 miles W. of Troupe, Smith County.
5. Limonite, from 1¼ miles N. of Nechesville, Anderson County.
6. Massive Limonite, from Fincastle, Henderson County.
7. Limonite, from Cherokee County.
8. Limonite, from 3¼ miles N. E. of Mineola, Greer headright, Wood County.
9. Limonite, from 2 miles S. W. of Pine Hill, Wood County.
10. Limonite, from Butler survey, N. E. corner of Upshur County.
11. Limonite, from ¼ mile east of Lake Fork, 2 miles N. of railroad, Wood County.
12. Limonite (concretionary), from N. E. corner of Upshur County.
13. Limonite (concretionary), from Gonzales headright, 3 miles N. W. of Pine Mills, Wood County.
14. Limonite (concretionary), from 3 miles S. by E. of Coffeeville, Upshur County.
15. Limonite (concretionary), from Lilly headright, Marion County.
16. Limonite (echreous), from McKinney-Williams survey, N. W. corner Marion County.
17. Limonite (ochreous), from 2 miles S. W. of Lasater, Marion County.
18. Limonite (laminated), from Butler survey, N. E. corner of Upshur County.
19. Brown ore (laminated), from 8 miles S. E. of Tyler.
20. Limonite (laminated), from Fincastle, Henderson County.
21. Limonite (laminated), from 8 miles S. E. of Palestine, Anderson County.
22. Clay Ironstone (limonite), from 3 miles W. and N. of Pine Mills, Wood County.
23. Clay Ironstone, from a well 8 miles S. of Grand Saline.
24. Mammillary Limonite, from 6 miles S. E. of Tyler, Smith County.
25. Brown Massive Iron Ore, from 5 miles west of Jacksonville.
26. Iron Geode, from Berry Hill, Marion County.
27. Iron Ore (conglomerate), Leverett's Hill, Marion County.
28. Poor fossiliferous ore, from 4 miles N. of Jacksonville.
29. Iron Ore, from Lasater Hill, Marion County.
30. Brown Hematite, from Cherokee County.
31. Iron Ore, from 5 miles S. of Troupe.
32. Iron Ore, from W. H. Crain survey, line of Cass and Marion counties.
33. Iron Ore, from Drury Richardson survey, 8 miles N. of Jefferson.
34. Iron Ore, from J. W. Duncan survey, 9 miles north of Jefferson.
35. Iron Ore, from 8 miles N. of Jefferson, J. A. McKinney survey.
36. Iron Ore, from Berry Hill, Marion County.
37. Siliceous Iron Ore, from 8 miles E. of Fairfield.
38. Conglomerate Iron Ore, from 5 miles S. of Palestine.
39. Conglomerate Iron Ore, from 14 miles E. of Crockett.
40. Ferriferous Sandstone.
41. Conglomerate.

	Peroxide of Iron.	Alumina.	Magnesia.	Lime.	Sulphuric Acid.	Silica.	Loss by Ignition.	Phosphoric Acid.	Total.	Metallic Iron.
1*...	59.86	....	......	......	....	....	....	......	....	41.90
2*...	68.80	3.40	Trace	Trace	....	13.36	13.70	0.12	99.38	48.16
3†...	73.60	9.89	......	Trace	....	10.06	6.75	Trace	100.30	51.52
4†...	57.09	12.56	.....	Trace	....	15.33	15.05	Trace	100.03	39.96
5†...	67.84	8.16	......	Trace	... ...	9.64	14.69	Trace	100.33	47.49
6*...	59.20	11.20	.. ..	Trace	....	16.20	13.45	Trace	100.05	41.44
7†...	60.35	4.24	Trace	0.33	......	25.13	9.24	0.26	99.55	42.25
8*...	39.78	8.42	Trace	1.06	0.18	40.40	9.50	0 31	99.65	27.85
9*...	44.98	6.82	Trace	2.27	0.02	36.70	9.70	0.16	100.65	31.49
10*...	66.09	6.91	Trace	1.81	0.37	11.85	12.40	0.28	99.71	46.26
11†...	42.84	7.86	Trace	2.10	1.04	40.60	6.10	Trace	100.54	29.99
12†..	48.65	12.65	Trace	2.30	0.26	26.07	10.30	Trace	100.23	34.06
13*...	68.23	5.17	Trace	0.86	0.34	14.50	10.20	0.57	99.87	47.76
14*...	80.78	2.22	Trace	0.88	0.02	4.30	10.47	0.38	99.05	56.55
15*[1]..	76.42	6.20	Trace	1.13	0.61	3.10	9.90	0.22	100.19	53.49
16*...	67.93	7.07	Trace	1.57	0.18	8.92	14.40	0.32	100.39	47.55
17*...	84.15	2.05	Trace	0.94	0.22	1.22	12.20	0.19	100.97	58.90
18†...	65.79	8.31	Trace	2.30	0 36	18.77	5.05	Trace	100.48	46.05
19*[5]..	57.25	30.634	0.805	1.235	1.45	8.18	....	......	100.119	40.08
20*...	64.30	10.70	.....	1.06	....	15.40	7.70	0.24	99.40	45 01
21*...	64.32	13.18	......	Trace	Trace	8.70	14.10	Trace	100.30	45.02
22†[5]..	48.96	4.54	Trace	2.10	0.31	36.27	7.25	Trace	100.63	34.27
23*[2]..	45.30	17.04	......	15.68	....	6.91	....	.. ...	97.25	31.71
24†...	66.10	8.20	......	Trace	....	10.79	14.27	Trace	99.36	46.27
25*[5]..	59.74	23.41	1.185	0.515	1.863	....	.....	.. ..	99.133	41.82
26*[3,5]	74.115	16.505	1.765	1.040	0.933	1.492	... ...	0.122	98.085	51.88
27*...	26.27	6.73	1.05	....	1.55	53.20	11.23	......	100.00	18.39
28*[5]..	44.805	18.495	4.415	0.560	4.40	18.425	8.73	......	100.00	31.36
29*[5]..	69.75	8.70	0.235	....	1.99	6.975	12.153	......	100.00	48.83
30*[4]..	43.67	....	......	....	0.0213	11.40	.... ..	......	....	30.57
31*...	20.46	....	......	....	....	....	....	......	....	14.32
32†...	61.20	1.10	......	Trace	Trace	27.33	10.57	Trace	100.20	42.84
33†...	79.06	0.69	......	1.50	Trace	6.04	12.68	Trace	99.97	55.34
34†...	65.79	19.96	. ..	Trace	Trace	0.98	13.90	Trace	100.58	46.05
35†...	60.44	19.56	......	Trace	Trace	6.77	12.95	Trace	99.72	42.31
36*[5]..	64.42	3.816	1.014	0.284	1.838	26.435	......	......	99.702	45.09
37*...	28.22	....	......	. ...	....	48.975	... ...	......	... .	19.75
38*...	60.05	....	......	....	... ...	24.48	....	.. .	....	42.04
39*...	63.75	....	... ..	...	.. ...	20.40	....	......	... .	44.63
40*...	12.21	....	......	....	... ..	74.35	....	.....	... ...	8.55
41*...	27.91	....	.....	....	....	47.10	....	......	....	19.54

* Analysis by J. H. Herndon.

† Analysis by L. Magnenat.

1 Ferrous oxide, 2.61. 2 Carbonic acid, 12.82. 3 Potassa, .364; soda, .485. 4 Insoluble residue, 33.50.

5 Oxide of manganese; No. 19, 0.565; No. 22, 1.20; No. 25, 0.420; No. 26, 0.1264; No. 28, 0.170; No. 29, 0.147; No. 36, 1.895.

BENCHES.

The existence of benches on the slopes of the iron ore hills has been referred to in several places, and requires some explanation. They are of very common occurrence, and form a marked feature in the topography of the country. Sometimes as many as five or six of these are seen in a vertical distance of 100 feet, and run out from the side of the hills to a distance of

from three to ten feet. As has been stated by the writer, in a previous report,* these benches can be formed in three different ways:

1. By landslides, which have carried down a portion of the top bed to a lower level, often giving the appearance of a second bed of iron ore, when it is only the edge of the upper one.
2. The alternation of hard and soft strata. The softer beds become eroded, and expose the harder iron ore, sandstone, or hard-pan.
3. By erosion in successive periods of elevation of the country.

It is probable that each of these causes has formed some of the benches, but they are usually so heavily covered by detritus that it is often very difficult to determine which has formed any certain bench. In the iron ore region of Cherokee, Anderson, and Smith counties, however, they are very often, if not most often, due to landslides. At first it might appear that the great number of such benches on a hill side, their occasional regularity, and their universal occurrence could not be accounted for by this explanation, but an examination of the form of erosion now going on in the country tends strongly to prove that this cause has operated, at least in a great number of cases. As we go over any of the iron-bearing highlands the ore bed is seen to be sunken as we near the brink of the hill, and this is especially true at the heads of ravines where springs gush out. It has already been stated that the iron ore is overlaid by sand and underlaid by a bed of greensand thirty to forty feet thick. Beneath this are interbedded sands and clays, all lying horizontally, or almost so. The springs rise sometimes above the iron ore bed, but more often between it and the greensand, and below the greensand. When the underground waters reach the outcrop of the bed along which they are flowing they appear as a spring, generally highly ferruginous, and giving rise to a small stream. In wet weather the flow from these springs is very strong, and besides carrying out the mineral matter in solution, they also transport in the state of mechanical suspension large quantities of sand from the beds through which the water has flowed before reaching the surface. This action gradually makes the sand strata porous and honeycombed, and the result is that it finally reaches such a stage of this condition that it gives way to the pressure of the overlying beds, sinks down, and causes the formation of a bench on the hill side. Of course more sand is carried from the part of the bed near its outcrop than back in the hill, and hence the reason that the benches generally slope toward the drop of the mountain, and also the reason of the downward slope of the ore on the edge of the summit.

There are many facts that tend to prove that such an occurrence as this has gone on.

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*Texas Geological and Mineralogical Survey. First Report of Progress, 1888, page 55.

1. There is generally found a cap of iron ore on the benches as well as on the top of the hill, and of the same nature and the same thickness in both places. Yet where a clean section of the deposit underlying the top ore bed is seen, it is very rare that lower beds are found, and when they do occur they are thin, discontinuous, and of a physically different ore than the main bed. This would tend to show that the ore bed found on the benches belonged at the level of and had once been part of the main bed.

2. The greensand underlying the ore bed varies from thirty to forty feet thick, yet when there are several benches on the hill slope, and we measure the vertical thickness of the greensand from the upper ore bed to the base of the outcrop, it often appears almost a hundred feet thick. This can only be explained by supposing the edge of the hill to have slipped.

The alternation of hard and soft strata doubtless causes the formation of many benches, but this generally occurs in the country north of the Sabine, where almost all the benches are due to it. The soft strata over a harder one are worn away, until the eroding agencies come to the hard floor, which temporarily arrests the denudation, and hence arises a bench. The number of benches that can be explained as sea beaches, or river and lake terraces, is exceedingly doubtful, and the want of contour maps, as well as the concealed condition of all the strata, makes it still more difficult to determine the extent to which this cause has operated. No satisfactory work can be done in the matter until good maps are obtainable.

BUILDING STONES.

Though the beds underlying the whole of East Texas are characterized by their soft and a more or less incoherent nature, yet there are very often found spots in these strata that have become hardened by local chemical action. Such places, though limited in area, are very numerous, and supply a most valuable source of structural materials for local use. They are at present rarely used except for foundations, chimneys, and such purposes, but many of them are capable of being applied to much more extensive structures. These rocks may be divided into two classes:

1. Sandstones and Claystones.
2. Limestones.

SANDSTONES AND CLAYSTONES.

The most important of the sandstones are a series of local and limited deposits formed by the action of ferruginous solutions on the original loose sands. This variety varies from a comparatively soft friable mass to a

compact hard and flinty rock; from yellow to very dark brown in color, and from one to twenty feet thick. Such rocks are found everywhere throughout the East Texas region, and are often used for foundations and chimneys. They occur plentifully in the bluffs of the Angelina at the mouth of Walker Creek, and on the Neches River west of Gent, in the shape of a soft friable sandstone. Sometimes it is associated with pebbles of iron ore. Two miles east of the Neches, on the Gent road, is seen a very hard dark brown sandstone about four feet thick, capping a small knoll. Similar deposits are of very frequent occurrence on the slopes of the iron-bearing hills and ridges. Four miles north of Jefferson it is seen in some places twenty feet thick, and generally of a very friable nature. The State Penitentiary at Rusk is built of a soft yellow sandstone, containing specks of altered glauconite and a few casts of fossils. This was obtained from a bed ten feet thick and immediately underlying the main iron-bearing greensand bed. It is soft and easily cut with a saw. A rock very similar to this is found capping Cook's Mountain, three miles west of Crockett, in Houston County. It is a friable sandstone, and composed of siliceous sand with specks of glauconite and mica, is of a yellow color, contains many fossil casts in places, and shows considerable cross-bedding. The so-called "mountain" rises a little over one hundred feet above Crockett, is 600 yards long from northwest to southeast, and from 50 to 100 yards wide. The greensand bed which directly underlies the brown laminated iron ore stratum has often become yellow and hardened to a sufficient degree to be utilized as a building stone. In the region where it occurs it is very extensively used for fireplaces and such small structures. It is of a chalky or waxy consistency, dense and compact in structure, and easily shaped into the desired form by an ax or saw. On this ease with which it can be cut, and also a certain toughness which it preserves in spite of its softness, depends its universal use wherever it can be found. It is locally known as "yellow rock," "yellow sandstone," or "gumstone." The greensand bed varies from thirty to forty feet thick, but it is only in parts of it that the hardening process has gone on to a sufficient extent to make it available for building purposes. These indurated places vary from one to ten feet thick. Sometimes the greensand has become hardened without losing its green color, and in such cases we have a green rock of very similar nature to the yellow one just described. Such a material is found in Doyle's Gap and on the slope of the Mount Selman iron range, in Cherokee County. The glauconite in this green rock is generally mixed with a large amount of clay of the same color, and in some places the clay almost entirely replaces that mineral. This presence of clay probably accounts for the hardening of the bed, as it has acted as a cement in indur-

ating the glauconite. Sometimes, also, finely disseminated carbonate of lime is the cementing material in such rock.

Occasionally there is found in the East Texas region a hard white sandstone, often approaching quartzite in consistency, and exceedingly tough. In fact, it is so tough that it has not yet been put to any practical use by the farmers in the neighborhood, as they are unable to handle it with the implements at their disposal; but it is a beautiful stone, and if properly quarried would be a very valuable one. The largest deposit of this seen is on the old San Antonio road, two miles southeast of the town of Alto, in Cherokee County. The road skirts it or goes over it for about a mile. It varies in thickness from one to four feet. Its surface is pierced by holes, often running down for several inches and varying in diameter from one to two or more inches. They are often coated with a rusty crust, and have probably been formed by the decomposition and removal of iron pyrites. This presence of iron pyrites also accounts for the rusty crust and for the occasional rusty specks found in the interior of the rock. It directly overlies the fossiliferous greensand of the region, and possibly occupies the same horizon as the brown laminated ore elsewhere in the county. Similar rocks are seen three miles west of McKee's Mill, where it is from one to two feet thick and covers a small area, and a variety of it from four miles west of Jacksonville is said to have been very successfully used as a millstone. About five miles northeast of Rusk, on the Conway survey, is seen a similar stone, three feet in the thickest part, and covering a small area of only a few square yards. Here it is associated with sandy and clayey strata about 150 feet below the level of the greensand bed. This exposure shows that the white sandstone is not confined to the horizon occupied by the Alto bed, i. e., directly over the greensand. The origin of this sandstone, which in its hardness and toughness is in such contrast to the other East Texas deposits, is to be found in the induration of beds of clayey sand by silicic acid solutions. Many of these beds become converted to a soft friable rock, even when dried alone by exposure to air, and the infiltration into them of surface waters containing silicic acid would add not only toughness, but also the semi-quartzite appearance often seen. The fact that many of the surface waters in the sandy region of East Texas contain silicic acid explains the source of this cementing material in the sandstone.

On the Rio Grande, the same beds that are soft and incoherent to the northeast have become hardened into friable sandstone, and sometimes, though rarely, into tough siliceous rock. The cause of this greater amount of induration in this region is due to two causes, one climatic, and one chemical.

1. In the dry hot climate of the Rio Grande there is a greater tendency

for rocks containing a cementing material to solidify than in the comparatively moist and mild climate to the north.

2. There is a greater amount of carbonate of lime disseminated through the sand beds of the Rio Grande than to the north. This acts as a cement, and solidifies the mass. A rock of this kind is extensively worked near Laredo, for building and paving purposes. It splits easily into slabs, is highly calcareous, and often very hard.

The sands of the Fayette Beds frequently are sufficiently hardened to be used for building. Sometimes they have been converted to a massive translucent quartzite by the solidifying action of waters containing silicic acid. At Quarry, in the northern part of Washington County, large quantities of this rock are taken out and shipped to Galveston and Houston for building foundations, jetties, etc.

LIMESTONES.

The limestones of the Tertiary region of East Texas are rare, but where they do occur they often offer an excellent source of durable and strong building stone. They are generally hard, highly siliceous, and of a gray color. They are of limited extent, and probably occur as lenticular beds. They are usually in association with salines, though not invariably so. There are also found white limestones, like that at the Saline, in Anderson County, but these are rare, and better adapted for iron smelting than for building stones. As none of the gray limestone beds have as yet been seen by the writer, they can not be treated in detail. Rocks of this kind from a saline in eastern Freestone County are used in some of the railroad culverts east of Oakwoods, in Leon County. They are also found in the Saline in northern Smith County, and also in a similar locality in the southwestern corner of the same county. The large nodules of limestone at Port Caddo, in Marion County, are said to have been broken and used for paving streets in Shreveport, La. On the Rio Grande, at Roma, a Quaternary bed composed largely of white limestone carrying a variable quantity of rounded river pebbles is sometimes used for building purposes. In that dry climate it answers the purpose excellently, though a moister atmosphere would doubtless rapidly decompose it.

Thus it will be seen that East Texas, though as a rule underlaid by soft strata, contains also many localities of harder rock, and there is scarcely a town in the country that can not get sufficient rock, at least for foundations, and in many places for more extensive structures.

CLAYS.

Clays suitable for the manufacture of fire brick, earthenware, and even of fine china, are found in East Texas. Two companies are now engaged in making

pottery at Athens, in Henderson County. The clay used occurs in the town, and the articles manufactured are fire brick, tiles, sewer pipes, jugs, etc. The names of the companies operating are The Texas Fire Brick and Tile Company, and The Southern Pottery, Tile, and Brick Company. The bed of clay used varies from twelve to eighteen feet thick. It is underlaid by pure white siliceous sand and overlaid by a red sandy clay. The pottery clay is of a very light gray color, becoming almost white when dry. It is massive and exceedingly plastic. The works produce daily 10,000 fire brick and 2000 six-inch sewer pipe, besides pipe of other sizes. The Southern Pottery, Tile, and Brick Company produce ware equal to a cubic content of 1000 gallons daily, consisting mostly of jugs, pots, and earthenware dishes. Good clays are also found just outside of Jefferson, Marion County, on the road to Kellyville; on Town Creek, near Rusk, Cherokee County, and six miles south of the town, besides in many other parts of the timber region.

The adaptability of the great beds of clay in the lower part of the Fayette series for economic purposes can not be determined until further tests have been made, but there is little doubt that many of them will prove of great value, as they are often remarkably free from iron. Clays suitable for the manufacture of brick are of universal distribution in Eastern Texas, and there is scarcely a town in that region that can not and does not make brick from material obtained in its immediate neighberhood. In places the clay contains a certain admixture of sand, suiting it for the manufacture of a brick which, though not so beautiful as some others, is remarkably durable. Such bricks are of a deep red color, and often contain black spots.

GLASS SANDS.

Sands suitable for the manufacture of glass are found in some places in East Texas. Three miles north of Jacksonville, in Cherokee County, on the line of the Missouri, Kansas and Texas Railroad, are found large quantities of a pure white siliceous sand. Such sand is also found underlying the clay bed at Athens, and elsewhere. The sand beds of Texas are, however, so far as I know them, generally too much impregnated with iron, either in the shape of oxide, iron pyrites, or of glauconite, to be of value for glass making. The presence of clay in most of them is also injurious. Consequently it is only in a few places, like those just mentioned, that it occurs in an available state

LIME.

Though lime is almost universally distributed through the beds underlying East Texas, it is generally in such small quantities and so finely disseminated

that it is useless for manufacturing purposes. It usually occurs scattered through the beds in the shape of nodules, or as a cement in the sandy strata. In the few places where lime has been found in quantities it is generally too siliceous to be used for the manufacture of iron, though it might with great advantage be burned for agricultural purposes. It is in this connection that the Cretaceous inliers or limestone "islands" described on page 33 are of great importance, as they are composed of very pure carbonate of lime, and are the only source of such material in East Texas. They are found in Anderson County, Texas, Southwestern Arkansas,* and in Louisiana.† Probably a careful search will still farther prove their existence in East Texas. The deposit in Anderson County is destined to be of the greatest value as a flux for the iron ores of that county and the surrounding region.

A hard bluish-gray limestone is found at Saline, in the northern part of Smith County; also under similar conditions in southwestern Smith County; also at the Freestone County saline, two miles east of the town of Butler. Large concretionary masses of limestone, sometimes weighing over two tons, are found on the Big Cypress River, near Port Caddo. These are said to have been hauled to the old Kelly furnace, in Marion County, a distance of twenty-two miles, as a flux. They are also said to have been taken down the Big Cypress and Red rivers to Shreveport for use in paving.

MARLS.

The marls of East Texas are numerous, and, varying as they do in physical composition, differ considerably in their agricultural value. They are not as rich in fertilizing ingredients as some found in other States, but they are of great importance locally, inasmuch as they contain the ingredients that the soils of the surrounding country most need, i. e., potash, soda, phosphoric acid, lime, and magnesia. The basis of all good soil is silica or alumina, represented respectively by sand and clay, and associated with smaller quantities of lime, magnesia, iron, manganese, phosphoric acid, potash and soda salts, and ammonia in the form of decayed animal and vegetable matter, besides other substances in smaller quantities. A soil composed exclusively of silica or alumina, or both, would be worthless, but with the other ingredients in proper proportions, they form the richest of all lands. Plants draw their sustenance from three sources—the air, the rain, and the earth. From the air they take carbonic acid and nitrogen (in the form of ammonia) and water (in the form of a vapor). From the rain they take the carbonic acid

* Geological Survey of Arkansas, Vol. 2, Mesozoic Geology, R. T. Hill, 1889.

† "Summary of Results of a late Geological Reconnoisance of Louisiana," E. W. Hilgard, American Journal of Sciences and Arts, Vol. XLVIII, Nov., 1869, p. 342.

and nitrogen (ammonia) which it has taken into solution in its passage through the atmosphere, and also part of the rain itself. From the earth they take up, in solution, the mineral constituents necessary for their growth, as well as more nitrogen. The organic materials, i. e., the carbon, hydrogen, oxygen, and nitrogen contained in the carbonic acid, water, and ammonia, go to form the main part of the fibre and juices of the plant, while the inorganic materials, i. e., the mineral constituents, are associated with them in comparatively very small but yet absolutely indispensable proportions. The mineral constituents vary considerably in different plants, but whatever the mineral requirements of a plant are, they always remain constant. If there is not enough of a certain mineral in the soil, the plant is not content with taking up a smaller percentage of it and growing to its normal size, but it takes up all it can get, uses it at the same rate as the composition of the plant requires, and, when it can get no more, it ceases to grow. The result is a small, deformed, and weak plant; and, in the case of corn, wheat, etc., a small crop of poor, half-sized grain. The atmospheric agencies are continually decomposing the mineral matter locked up in the insoluble part of the soil, and making it available for plant food, thereby constantly replenishing the store of this material. But the process of agriculture generally abstracts mineral food faster than it is supplied. Hence the necessity of returning it to the soil in the shape of marls, manures, or of artificial fertilizers. These minerals are usually potash or soda, phosphate of lime, ammonia, and sometimes lime and magnesia. Though the marls of this region contain only small proportions of these ingredients, yet it is sufficient to be of great agricultural value. It will be seen by the table of analyses that almost all of them contain potash, soda, phosphoric acid, lime, and magnesia, all of which are ingredients useful to many exhausted soils.* The first three ingredients are of special value, as the supply of them is very apt to run short in East Texas soils, but the supply of lime and magnesia is generally larger, and therefore less apt to need replenishment. The first three of the analyses given below are of altered greensand, such as underlies the iron ore bed of Cherokee, Anderson, and other counties, in the form of the yellow substance known as "yellow sandstone." They are valuable for local use, and their very general distribution makes them particularly accessible. No. 4 is a green clay stratum in the greensand bed of Cherokee County. Besides its alkalies, its forty-nine one-hundredths per cent of phosphoric acid makes it more valuable

*Much of the soda and potash in these marls is in the form of insoluble silicates, which are not immediately available for plant food. But they gradually decompose under the influence of the atmosphere and the vegetable acids in the soil, and are finally converted into carbonates and taken up into solution. Part of the silica shown in the analyses is also in a soluble form, and is of great service to the growth of plants.

than the last three marls. Similar beds are found in many places in the greensand country. No. 5 is a clay marl from Grand Saline Station, on the Texas and Pacific Railroad, in Van Zandt County. It is of a gray color with specks of glauconite, and could be profitably used on the sandy soils of the neighborhood. No. 6 is a similar marl, from a different part of the same bed, and is poorer in soda. No. 7 is from a well on the land of Joel King, ten miles northeast of Canton, Van Zandt County. The soils of Van Zandt County are mostly very sandy, and the application of these marls to them would doubtless be accompanied with very great benefit. No. 8, from one mile south of Elkhart, Anderson County, and No. 9, from fourteen miles east of Crockett, Houston County, are exceedingly valuable marls, not only on account of their alkalies, but on account of their phosphoric acid. The large percentage of lime and magnesia would also be very useful on those soils which are without them. Both marls are identically the same; they consist of a mass of yellow altered greensand containing a great number of fossil shells, which account for the large amount of lime present. No. 10 is the greensand that is found in digging wells in Palestine on the hills south of the International and Great Northern Railroad. It is comparatively soft, but sometimes hard layers occur in it. It contains many fossil shells. The rich red mulatto soils immediately around the town, being composed of the decomposed surface of this material and of similar beds, do not require a marl of this kind, but it might be used to great advantage on the sandy lands to the north and south of the town. The amount of phosphoric acid and magnesia found here is larger than that of any of the other marls in the list of analyses, and it is undoubtedly one of the most valuable beds yet examined by the writer. Nos. 11, 12, 13, and 14 are samples of undecomposed greensand from the bed underlying the iron ore in Cherokee County. They are green in color, loose and easily handled, and could with great advantage be used on the soils of the neighborhood. No. 11, from Mount Selman, has been used in gardens at that place with most satisfactory results. Though soft when first dug, this marl is liable to become somewhat harder on exposure.

	Water.	Silica.	Alumina.	Oxide iron.	Lime.	Magnesia.	Phosphoric acid.	Sulphur.	Sodium oxide.	Potash.	Sulphuric acid.
1 . .	2.66	19.85	30.23	33.82	10.80	1.21	......	....	......	... ..	......
2 ...	......	19.91	31.25	37.89	.. ...	0.48	......	1.64	5.48	0.8	..
3 ...	4.95	32.20	18.24	28.96	2.67	Trace	0.11	.....	6.39	3.05	0.02
4 ...	......	25.8	42.20	19.75	0.90	0.80	0.49	......	2.5	0.26	......
5 ..	......	50.652	......	23.534*	.. ..	... ..	......	......	2.216	2.631	......
6 ...	....	75.286	......	....	......	.. ...	......	......	0.302	2.929	......
7 ...	......	68.114	......	20.077*	.....	.. .	......	......	2.178	2.625	.. ..
8 ...	5.52	21.36	13.65	32.21	19.00	0.32	0.61	.....	3.39	0.71	......
9 ...	6.10	29.12	14.30	42.1	11.21	0.72	0.58	......	1.58	0.62	......
10 ...	......	16.10	13.09	49.46	9.80	1.48	1.88	......	2.26	0.04	......
11 ...	5.65	20.95	16.28	47.62	1.81	1.46	. ...	.....	3.94	0.93	......
12 ...	5.85	25.95	11.20	45.25	5.20	1.40	0.38	... ..	2.12	0.13	......
13 ...	6.00	30 85	16.87	36.83	0.60	1.46	0.41	......	3.44	1.72	......
14 ...	6.35	32.00	20.66	34.94	0.66	1.14	0.42	......	3.77	0.66	......

* Iron and alumina.

LIGNITES.

The lignites of Eastern Texas have been mentioned in many places in this report in the description of the geology of the various parts of the region. They consist of the decayed vegetation which covered the region during the time that the lignites and their accompanying sandy and clayey strata were being deposited. In them are found the remains of trunks of trees, branches, and leaves, with impressions of reeds and other bog or swamp flora. In fact every lignite bed in the region represents the position occupied by an ancient swamp or coast lagoon. Probably most of the Texas lignites were formed in bayous and lagoons on the coast, and the vegetable matter was carried to them by rivers.

Such places were probably heavily timbered, and year after year the trees dropped their leaves and dead branches on the moist ground. Here they collected and were mixed up with dead reeds, moss, grass, etc. As the trees themselves died they also lay down in the same grave, and rotted in the same boggy waters as their leaves and branches, until often a great thickness of decayed vegetable matter had collected. Then, from some cause, either from a change of elevation of the land or an increase of rainfall, and hence of surface waters, these beds were submerged. The waters passing over them deposited sand and clay on top of the vegetable matter, and often reached a thickness of several hundred feet, compressing it by their weight into a solid mass. Hence the lignite beds as they now exist, overlaid and underlaid by sands and clays. It might happen that these same sand and clay beds that had been deposited over the vegetable matter may be again raised above the water level, form the bottom of another bog, collect more dead trees, leaves, etc., and again be submerged to be covered by sand and clay, in the same way

as the first or underlying bog. Hence the reason that we often find two or more beds overlying each other and separated by sands and clays. The vegetable matter in these beds has in some few cases preserved its original shape, but in the vast majority of lignites it has been altered to such a degree that we see simply a solid mass, varying from dark brown to black in color, and showing no trace of its former existence as a tree, reed, or leaf. The lignite also varies very much in its physical character. At times it is a soft amorphous mass with no structure, a dull earthy lustre, and easily crumbled when exposed to the air. At others it is harder, with a bright and often a brilliant jet black lustre, breaking with a cubical or conchoidal fracture, and though soft, yet not so easily crumbled as the first variety. Between these stages there are found all gradations. The difference in character is probably not only due to the conditions of deposition of the vegetable matter in the original bog, but also to chemical changes which have since taken place, and to the different pressure of the overlying strata. It can not be due to any disturbance or folding of the strata, as they all lie almost horizontally or dip gently to the east or southeast, and show no signs whatever of any such disturbance. Yet we often find beds of these two different varieties of lignite in strata of the same material and exposed to exactly the same physical and meteorological conditions. Hence we are brought down to ascribing these differences either to different conditions of deposition, or to the chemical action which has gone on since the deposition of the lignite. A strong proof of this is shown in the case of the San Tomas coal, page 96.

These lignite beds occur all through East Texas, from the top of the Basal Clays on the western edge of the timber to beyond the middle of the Fayette Beds, sometimes to within a hundred miles or less of the gulf coast. They are not confined to any special strata in this region, but occur at intervals all through it. They are, as is natural from their mode of formation, of uncertain areal extent, and occur as lenticular beds in the overlying and underlying strata. Yet they are so numerous and often so thick that if they were to be used on a large scale, vast quantities of the material could be obtained. They vary in thickness from a fraction of an inch to over twelve feet. On the Sabine River these beds are seen in many places, cropping out on the bluffs in Van Zandt, Rains, Smith, Wood, and many other places on the lower part of the river. In many parts of Van Zandt County, especially between Canton and Grand Saline, lignite is found in most all the wells, often giving them a strong mineral taste from the decomposition of the iron pyrites. Near Alamo, Cass County, lignite has been worked to some extent, and occurs in three different beds (page 35). Similar beds crop out on the Trinity River, in Anderson, Houston, and other counties. In Henderson County it is found on the land of W. E. Jones, three miles southwest of Athens. In

Cherokee, it is found in many places south of Alto, and thence on into Angelina, Nacogdoches, Rusk, and other counties. On the bluffs of the Brazos, lignite is exposed in various places, from the northern part of Milam County down to the southern part of Burleson County. The largest bed seen here is at what is known as "Calvert Bluff," in Robertson County, near the town of Calvert. A section of this bed is given on page 26. It will be observed that there are two separate beds, the upper one twelve feet thick, and the lower one two feet, and separated by two feet of clay. The lignite is black, friable, of a somewhat woody structure, and crumbles on exposure to air. Both above and below this point on the Brazos are seen numerous beds varying from one to five feet thick. On the Colorado River, many lignite beds crop out in Bastrop and Fayette counties. Both above and below the town of Bastrop they are very numerous, and form an almost universal accompaniment of the sandy and clayey bluffs, varying from one to five feet thick. Along the river, in the western part of Fayette, they are seen near the mouth of Barton Creek, and in the First and Second Chalk Bluffs. See page 52. Some eight miles by river above La Grange is seen a bed ten feet thick.

SAN TOMAS COAL MINE.

This is the only place where fuel is mined on any considerable scale east of a line drawn between Eagle Pass* and Dallas. A section of this is given on page 43. The coal bed is two and a half feet thick, and separated in the middle by a two inch seam of hard black clay.† The coal is jet black, highly glossy, and has a conchoidal fracture. It is generally massive, though sometimes it has the structure of bituminous coal. It is light and friable, and has the appearance of being an altered lignite.

This material has proved a very serviceable fuel. and is especially valuable in a country like Southern Texas, where there is no other coal, and where wood is very scarce. The enterprising manager and owner, Mr. C. B. Wright, has built a railroad, the "Rio Grande and Pecos," from the mine to

*Considerable coal is mined a few miles northwest of Eagle Pass.

†As will be observed in the section, the coal is both underlaid and overlaid by clays containing thin seams of true woody lignite. The presence of these throws some light on the cause of the metamorphism of the coal into its present shape. If it had been due to any disturbance in the strata of the surrounding country or connected in any way with the existence of the eruptive knobs to the west and northwest, we should expect to see all the beds metamorphosed, and not the central one only, as they are so close together that any such influence that would affect one must also affect the other. Therefore we are driven to the conclusion that the change of character of the material must have been due either to the peculiar conditions surrounding its deposition, or else to the chemical action which has taken place since that time. Probably both these causes have operated, the chemical cause possibly having been started by the physical one.

Laredo, a distance of twenty miles, thus facilitating the shipment of the coal to the various markets. It is extensively used on the Mexican International Railroad, and for steam and household purposes in Laredo, and has already become an important factor in the welfare of the region. When the mine was visited by the writer, in May, 1889, the output was 100 tons a day.

USES OF LIGNITE.

The San Tomas coal is so vastly superior to any of the East Texas lignites that it can not fairly be classed with them, and therefore the following remarks are not intended to refer to it. The lignite beds have not yet been worked to any considerable extent. Some of the material has been taken out at the following places: In Raines County; at Alamo, in Cass County; some three miles southwest of Athens, Henderson County; at Calvert Bluff, Robertson County; and in other places in small quantities; but so far as the knowledge of the writer goes, it has in every case been attended with unsatisfactory results. There are three causes for this:

1. The lignite, even when it is sun-dried, contains a high percentage of water, ten to twenty per cent, and when it is burned a large amount of the heating power of the fuel is consumed in evaporating the moisture, and is absolutely lost for all practical purposes. This water, in the sun-dried material, is chemically combined with the lignite, and can not be removed without decomposing it. Hence the popular saying that the lignite "burns without heating."

2. Most all the lignites have a strong tendency to crumble when exposed to the air, and a large part of it is wasted by being carried up the flues of a furnace even by an ordinary draft. Also, a finely crumbled fuel is difficult to handle in a furnace, and its transportation is expensive, and accompanied by a large amount of waste.

3. The part of East Texas where lignite is found is heavily timbered, not only with pine but with hardwoods. Railroads in many places can have this fuel placed on the track for $2 to $4 per cord, and it requires a very good and cheap coal to compete with that price for railroad or furnace purposes. It might be said that the wood will run out, and the lignite will then be used. But as the hardwood of East Texas is increasing every year, and spreading over areas that were once prairies, the outlook in this direction is not encouraging. As the value of lignite will not stand transportation, it can not, except under special conditions, be sent into the regions where wood is scarce.

There are, however, uses to which lignite *can* be applied:

1. The better grades can be used for household purposes.

2. It can be ground and pressed into bricks, with some cementing substance like asphalt or coal tar, and thus gotten into a much more serviceable shape

than that in which it naturally occurs. This does away with the inconvenience of having it crumble. Such bricks are considerably used in France and Belgium* for railroad and other purposes.

3. Lignite of a black color, in a finely powdered state, has been used in England, under the name of "Cologne Earth," as the basis of a black paint.

4. Lignite has been successfully used in place of bone-black in clarifying sugar.

ANALYSES OF TEXAS LIGNITES AND COAL.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Lignite—Rockdale, Milam County	19.925	52.425	22.000	5.650	1.235
Atascosa County	13.285	59.865	18.525	8.325	2.360
Athens, Henderson County	9.100	42.200	7.375	41.325	0.625
Rusk County	16.825	46.325	31.475	5.375	1.090
Calvert Bluff, Robertson County	16.475	58.400	18.675	6.450	1.330
Shelby County	18.260	43.510	29.530	8.700	2.460
Leon County	14.670	37.320	41.070	6.690	0.250
Rockdale, Milam County	13.800	43.550	36.830	5.320	1.350

ANALYSES OF LAREDO AND EAGLE PASS COAL.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Laredo Coal	2.5	51.05	39.1	7.35	1.5
Eagle Pass Coal	3.675	39.42	41.7	15.205	0.81

MINERAL SPRINGS.

Springs are of very frequent occurrence throughout East Texas. Sometimes they are very pure, and almost entirely free from any mineral matter, while at other times they are highly charged with iron, sulphuric acid, and salts of lime, magnesia, alumina, and alkalies. Iron springs, however, are by far the most plentiful of all the mineral waters, and it is an exceedingly common occurrence to see chalybeate waters arising from Tertiary strata. The interstratification of sand and clay beds, representing as they do alternate permeable and impermeable layers, is peculiarly favorable to the existence of local springs. Water falls on the sandy surface of a hill and runs down between the loose materials until it meets a clay bed. This proves impassable on account of its impervious nature, and the water, thus deflected from its downward course, runs over the surface of the clay until it reaches the outcrop of the bed in a hillside or river bluff, and here gushes out as a spring. The ferruginous springs derive their iron from the beds through which they pass. The sandy soils are often bleached on the surface, while

*Compare First Report of Progress Geological and Mineralogical Survey of Texas, 1888, p. 20.

below they are highly ferruginous. This is sometimes due to the difference in the strata, but is also often due to the bleaching or deferruginizing power of waters passing through decaying vegetation, such as leaves, roots, dead trees, etc. The iron in the sand is in the form of sesquioxide, which is insoluble in pure water, but slightly soluble in water containing carbonic acid. The rain water falls on the decaying vegetation of the surface, becomes highly charged with carbonic acid generated by it, and percolates into the underlying sand bed. Here it takes up its portion of iron, and, when it finally appears again as a spring, it is highly charged with it. This, on exposure, is again oxidized, and appears in the form of a rusty, oily looking scum, often mistaken for petroleum; or as a brown slimy sediment in the bottom of the spring and the stream running from it. Frequently part of the oxide of iron is precipitated before the stream appears on the surface, and forms layers of hard rusty scales on the top of the clay bed over which it is running.* Many iron springs are also formed by the decomposition of iron pyrites in the sandy and clayey strata. This mineral breaks up with the formation of sulphate of iron and sulphuric acid, both of which are taken up in the subterranean waters and appear again on the surface as ingredients of chalybeate springs. The sulphuric acid sometimes attacks the clay, taking up part of the alumina contained in it and forming alum. Also, it attacks any lime, magnesia, potash, or soda salts that may exist in the strata, and forms gypsum from the lime, epsom salts from the magnesia, and soluble sulphates from the potash and soda; hence the presence of these materials in many mineral springs.

Springs such as have been described are very numerous throughout East Texas. They appear in many hillsides, and especially on the bluffs of rivers, coating them with a rusty scum, and often cementing the loose strata surrounding them.

Hynson Springs are in Harrison County, six miles southwest of Marshall. Some of these are highly charged with iron, and others much less so. They also contain magnesia, lime, and alkaline salts. They are situated on a hill composed of sandy and clayey strata associated with iron ore, and rising 250 feet (barometric) above the town of Marshall. The summit commands a beautiful view of the surrounding country, and from it can be seen the forest-clad hills of Marion, Rusk, and Harrison counties to the north, south and west. To the east the country slopes off into the dense forests of Caddo and Sodo Lakes, and the Red River bottom. This property has been fitted up as a health and pleasure resort by the energetic owner, Captain Hynson, and promises to be one of the most popular places in the eastern part of the State.

* Lignite beds often, doubtless, supply much carbonic acid to the surface waters.

The Elkhart Wells are one mile southeast of the town of Elkhart, in Anderson County. They vary from thirty to sixty feet in depth, and have been sunk for the sake of the mineral waters they contain. A hotel is being built here and a health resort started. Some of the waters are comparatively free from mineral matter, while others are strongly impregnated with iron, alum and sulphur. Some of the old wells here are said to have smelled so strongly of sulphur as to have been obnoxious, and were filled up. The surrounding country is flat, low, and underlaid by sand and clay. These are brown from the presence of vegetable matter, and contain iron pyrites, lime, gypsum, and sulphur. It is doubtless from the mutual decomposition of these materials that the mineral matter in the water owes its origin. Some of the waters have a strong sulphur taste, and others have the pungent effects of alum and iron salts.

In the northeast part of the Musquez survey, in Mud Creek bottom, Cherokee County, are a great number of ferruginous and sulphur springs. The sulphur gives a strong taste to the water, and is deposited as a white sediment. The iron springs deposit a heavy sediment of hydrous oxide, and are closely associated with the sulphur springs. Twelve springs like these were seen in an area of about one square mile. In one of them a section of a large hollow gum tree has been sunk, making a beautiful clear basin within the sides of the trunk. Tradition says that General Rusk, almost fifty years ago, placed this tree here, and used to come every year from his home in Nacogdoches County to drink the water. Many other such springs are found in Eastern Texas, and many are the stories of wonderful cures that have been worked by them, but they have not yet been examined by the writer.

OILS.

The subject of oils in Nacogdoches, Angelina, and other counties has not been studied, and is left for future discussion. The oils and asphalt-bearing sands of Anderson County are briefly described below.

Ten miles east of Palestine is seen a series of black and chocolate colored sands lying horizontally and containing specks of mica. They are impregnated with bituminous matter, sometimes in the form of stiff sticky asphalt, and at others as mineral oil. In this neighborhood six wells were bored for oil by a Palestine syndicate in 1887, but little or no oil was found. The following two sections of borings, from data collected by Mr. J. L. Mayo, contractor, show the associations of the oil-bearing strata:

	Feet.
1. Soil	15
2. Rusty sand (some oil)	3
3. Chocolate-colored hardened sand	6
4. Alternate strata of sand and clay	34
5. Sand impregnated with oil	14
6. Clay and sand	43
7. Quicksand and water	6
8. Blue lignitic clay	159
9. Loose sand	30

1. Rusty clay	15
2. Quicksand	15
3. Light colored clay	22
4. Sand impregnated with oil	36

Oil-bearing sands were passed through in all the borings, and oil is occasionally seen in the creeks and springs of the neighborhood, but in none of the borings was it found to flow in any quantity. The reason of this is doubtless due to the fact that the oil-bearing stratum has been cut through by numerous creeks, and the oil, if indeed it ever did exist in any quantity, has been drained off.

The asphalt is probably due to the oxidation of the residuum of oil left in the sand. In many places the summer heat has softened it and caused it to run out of the sand, forming small pools on the hillsides.

This is especially true where the bitumen-bearing bed has been exposed on the surface, as it often is, and subjected to all the atmospheric influences. The amount of asphalt which could be obtained in this locality is not very large, and the asphalt-bearing sand is apt to run into oil-bearing sand, so that the quantity in any one spot is very uncertain. There is, however, enough of the material to be used for paving in the surrounding towns of Palestine, Jacksonville, New Birmingham, Rusk, and other places, and if the asphalt sand was used in its natural state on the streets and pavements it would greatly increase the welfare and comfort of these towns.

SALT.

The subject of salt and salines is also left for future discussion, as the time at the disposal of the writer has not permitted a full examination of the various localities. It may be said, however, that salt is found in many places in East Texas, and the future possibilities of a large product of that material are excellent. The deposits in Van Zandt County are described on pages 35, 36, and those in Anderson County on pages 33, 34. Besides these localities, salines have been found and worked in Freestone, Smith, and other counties. In all of these places, except in Van Zandt County, the salt was gotten from the brine of shallow wells.

A BRIEF DESCRIPTION OF THE CRETACEOUS ROCKS OF TEXAS AND THEIR ECONOMIC VALUE.

BY
ROBERT T. HILL, F. G. S. A.

A

BRIEF DESCRIPTION

OF THE

CRETACEOUS ROCKS OF TEXAS AND THEIR ECONOMIC USES.*

Based Principally Upon a Preliminary Section along the Colorado River from near Smithwick Mills, Burnet County, to Webberville, Travis County.

ROBT. T. HILL, F. G. S. A.

SYNOPSIS.

THE CRETACEOUS AREAS OF TEXAS BRIEFLY DEFINED.—General Statement of the Importance of the Underlying Rock Structure—Broadly Subdivided into the Black and Grand Prairie Regions.

THE UPPER CRETACEOUS, OR BLACK PRAIRIE, SERIES.—The Black Prairie and its Subdivisions—Its Underlying Rock Sheets—The Lower Cross Timber Sands—The Eagle Ford Clays—The "White Rock," or Austin-Dallas Chalk—The Exogyra Ponderosa Marls, or Main Black Prairie Beds—The Uppermost, or Sandy Glauconitic Beds.

THE LOWER CRETACEOUS, OR COMANCHE, SERIES.—The Grand, or Fort Worth, Prairie—Compared with the Black Prairie—The Trinity Sands, or Upper Cross Timber Beds—The Fredericksburg Division—The Basal Alternating, or Magnesian Beds—The Comanche Peak Chalk, and the Caprotina Limestone—The Occurrence of Flints in the Latter Beds—The Leander Beds—The Washita Division, or Fort Worth Limestone—The Exogyra Arietina Clays—The Shoal Creek Limestone and the Denison Beds.

TABULAR REVIEW OF THE CRETACEOUS SYSTEM OF TEXAS.—Economic Features of the Cretaceous System—The Agricultural Soils and Natural Fertilizers—The Building Material—Peculiar Adaptability for the Manufacture of Portland and Hydraulic Cements—Important Water Conditions—Mineral Products—Lines of Investigation for the Future.

The two series of rocks comprising the Cretaceous System occupy the area of the State known as the Black Prairie, the Grand Prairie, and the two Cross Timbers, and unstudied areas in the eastern and trans-Pecos regions of the State.

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*Most of the scientific facts contained in this paper have been published from time to time in various publications by the author, lists of which, with other references to the literature, fossils, and more technical points, have been published in Bulletin No. 4 of this Survey.

To these strata the State owes a large part of her agricultural and general prosperity, for they are the foundation of the rich black waxy and other calcareous soils of those regions.

In addition to their agricultural features they are the most productive source of building material, while adjacent to the parting between them, extending the entire length of the State and dependent upon their stratigraphy, is a remarkable area of natural and artesian wells, as seen at Fort Worth, Austin, Waco, Taylor, San Marcos, and elsewhere.

That these formations are of great economic value to the State, is also shown by the fact that they are the site of our principal inland cities, and the rich agricultural soils which surround them.

This is in general a chalky country, and uniquely Texan, so far as the United States are concerned, constituting a distinct geographic region, in every topographic, economic, and cultural aspect, and one which should not be confused with other portions of our country. It covers an area of over 73,512 square miles, or over one-fourth (28.27 per cent) of the total area of Texas, forming a broad belt of fertile territory across the heart of the State, from the Ouachita Mountains of the Indian Territory and Arkansas to the mountains of Northern Mexico, an area larger than the average American State, and equal to the combined area of all the New England States. One-third of this region lies north of the Colorado River, and the remainder to the southwest.

This region, with its many different prairies, each covered by its peculiar vegetation, its sweeping plains and diverse valleys, its undulating slopes clad with motts of live oak, its narrow strips of cross-timbers, its ragged buttes and mesas, presents a landscape varied, yet possessing as a whole an individuality peculiarly its own. All of these features, with their different tints and tones of soil and vegetation, with their varied conditions for human habitation, are but the surface aspects of the system of chalky rocks (chalky sands, chalky clays, and chalky limestones) upon which it is founded, and to which is primarily due every physical quality of the country. In fact it is the great chalky region of the United States.

The rocks originated as sediments of the Atlantic Ocean, laid down with great uniformity during two of the long epochs of subsidence and emergence, when the waters covered this region many hundred fathoms deep. These ancient sediments are now more or less consolidated and elevated into a fertile land, which is decomposing under atmospheric conditions into soils and debris, and in its turn being slowly transported to the ocean, where it will make other rock sheets. They now occur in regular sheets or strata, dipping beneath each other toward the sea, while the projecting western edges, each of which weathers into and imparts its individuality to its own peculiar

SIGNAL MOUNT—HOWARD COUNTY.

A Cretaceous Butte.

belt of country, outcrop in long narrow belts, sub-parallel to the present ocean outline. Thus it is that as one proceeds inland from the coast he constantly crosses successively lower and lower sheets of these formations. The oldest, or lowest, in a geological sense, of these outcrops, forms the Upper Cross Timbers, those above these make the Grand Prairie, the next sheet forms the Lower Cross Timbers, the next the Black Prairie, etc. Each of these weathers into a characteristic soil, which in its turn is adapted to a peculiar agriculture. Each has its own water conditions and other features of economic value. Some of these rock sheets, like the Upper Cross Timber country, may be comparatively unfertile in the region of outcrop, yet they may serve to carry the rain which falls upon the thirsty sands far beneath the adjacent country, where by artesian borings it becomes an invaluable source of water supply for a distant and more fertile region.

The Cretaceous country of Texas, as a whole, like the system of rocks of which the surface is composed, is separable into two great divisions, each of which in turn is subdivided into a number of subdivisions. These two regions are known as the Black Prairie and Grand (or Fort Worth) Prairie regions, each of which includes in its western border, north of the Brazos, an elongated strip of timber known as the Lower and Upper Cross Timbers, respectively.

I. THE UPPER, OR BLACK PRAIRIE, SERIES.

THE BLACK PRAIRIE REGION.—This occupies an elongated area extending the length of the State from Red River to the Rio Grande. The eastern border of the Black Prairie is approximately the southwestern termination of the great Atlantic Timber Belt. The Missouri Pacific and the International railroads from Denison to San Antonio approximately mark the western edge. A little south of the centre, along the Colorado River, from Austin eastward to the Travis County line near Webberville, the Black Prairie is restricted to its narrowest limits. Westward the Black Prairie is succeeded by a region with some superficial resemblance to it, which, on closer study, is found to differ in all essential points. This is the Grand, or Fort Worth, Prairie, or "hard lime rock region," described on page 116. The so-called mountains west of Austin are the remains of the Grand Prairie. In general, the Black Prairie region consists of a level plain, imperceptibly sloping to the southeast, varied only by gentle undulations and deep drainage valleys, unmarked by precipitate canyons. It is transected at intervals by the larger streams, whose deep-cut valleys, together with their side streams, make indentations into the plain, but not sufficient to destroy the characteristic flatness of its wide divides—remnants of the original plain, or topographic ma-

rine base level, which has not been completely scored by its still youthful drainage system. The altitude of the plain is between 600 and 800 feet. The surface of most of the Black Prairie region is a deep black clay soil, which when wet becomes excessively tenacious, from which fact it is locally called "black waxy." It in general is the residuum of the underlying clays, and contains an excess of lime, which, acting upon the vegetation by complicated chemical changes, causes the black color. It is exceedingly productive, and nearly every foot of its area is susceptible of a high state of cultivation, constituting one of the largest continuous agricultural regions in the United States. Large crops of cotton, corn, and minor crops are annually raised upon its fertile lands, and if there were facilities for proper transportation, it would soon be one of the leading districts of our country.

The Black Prairie is subdivided longitudinally into four parallel strips of country, differing slightly, and distinguishable only by slight differences in topography and in the underlying rocks. The easternmost of these divisions north of the Brazos River is distinguishable by the occurrence of sand in its black soil, and occasionally purer belts of sand. Between the Brazos and Colorado rivers, however, the sand is hardly perceptible. Immediately interior of this is located the largest and most characteristic area, which is marked by the stiffest of the black waxy calcareous clay soils. Upon digging throughout this area, the substructure is found to consist of a light blue or yellow calcareous clay, called by the residents "soapstone" and "joint clay," from its jointed and laminated structure. The surface, especially of the high undrained divides, is also accompanied in many places by minute depressions known as hog-wallows, which are produced by the drying, cracking, and disintegrating character of these excessively calcareous clays in poorly drained places. This, the main portion of the Black Prairie, constitutes fully two-thirds of its total area. The cities of Greenville, Terrell, Corsicana, and Kaufman are situated near the border of the sandy and black waxy strips. Manor, Clarksville, Cooper, Taylor, and Temple are all situated in the main black waxy belt.

An outcrop of "white rock" or chalky country, forming a narrow strip averaging two miles in width, from Red River to the Rio Grande, succeeds on the west the main Black Waxy strip. This chalk region is marked by a topography more rounded and deeper incised, but still void of the sharper lines of stratification that characterize the Grand Prairie region. It is usually treeless, but occasionally marked by clumps of handsome evergreens and oaks. The western edge of this chalky region, as seen at Oak Cliffs, near Dallas, at Sherman, Hillsboro, and other places, usually ends in an escarpment overlooking a valley containing the minor Black Prairie and Lower Cross Timber strips. It is upon this chalk that the most prosperous of the interior

cities of Texas are located, including Paris, Sherman, McKinney, Dallas, Waxahachie, Waco, Austin, New Braunfels, and San Antonio, all of which are dependent upon the agricultural products of the adjacent black prairies.

West of the "white rock" or chalky division, and generally at a slightly lower altitude, occupying a valley across the State, is a second narrow strip of black clayey land, of a nature similar to that of the main Black Waxy area, and likewise accompanied by hog-wallows. This is the country east of Denton and Whitesboro, in the Mountain Creek district of Dallas County, and along the line of the Missouri Pacific Railway, from Alvarado to Waco. The Sixth Ward of Austin is located upon these clays, and to them it is indebted for its characteristic black mud.

The Lower Cross Timbers—a narrow belt of forest country extending from the Red to the Brazos rivers—represent the westernmost strip of the Black Prairie region, and belong to it geologically, as will presently be shown.

GEOLOGIC SUBSTRUCTURE OF THE BLACK PRAIRIE REGION.

The substructure of the Black Prairie region is epitomized in the vertical section given beyond. The eastern margin is the outcrop of the Upper Arenaceous or Glauconitic division, No. 5 of our section. The main Black Prairie division, the surface of the marine clays, called the Ponderosa marls, No. 4. The white rock division is the outcrop of the Austin-Dallas chalk, aggregating about six hundred feet in thickness, No. 3. The minor Black Prairie, No. 2 of our section, is also composed of clays like those of the main division, and hence the similarity of the topography. Collectively with the Lower Cross Timbers, No. 1, these rock sheets, between which there is no stratigraphic break, represent the sediment deposited in the oceanic waters during a long continued subsidence, geologically known as the Upper Cretaceous period, for which collectively we have chosen the name of Black Prairie series. This Upper Cretaceous series* has five conspicuous stratigraphic and lithologic divisions, which approximately correspond with the topographic divisions of the Black Prairie above mentioned. These will now be described in ascending order, beginning with the lowest beds of the series.

* The continuation of the Upper Series has been well studied in the Northwestern States by the late Prof. F. B. Meek, the geologist who has contributed the most that is known concerning the Cretaceous formations of that country. His descriptions are found in a volume entitled "A Report of the Invertrebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country." By F. B. Meek, Washington, 1876. The series of Texas, while varying in many specific details from the section therein described, is so generically allied that it is evident those variations are merely local differences in the same great subsidence, and that nothing but long and arduous labor, yet to be performed, will reveal their exact affinities.

NO. 1. THE LOWER CROSS TIMBER SANDS.

From the Brazos River northward to Red River the base of the Upper Series is composed of a brown, more or less ferruginous, predominantly sandy, littoral deposit, resting unconformably upon various horizons of the semi-chalky beds of the Washita division, or top of the Comanche Series. These sandy deposits present an infinite variety of conditions of cross-bedding, clay intercalations, lignitic patches, and variation in fineness of size and angularity of the uncemented particles, characteristic of typical littoral deposits, while occasionally there are found fossiliferous horizons.*

In the vicinity of Denison these sands are covered by a Post-Tertiary sand, which confuses their identity there. South of the Brazos River, and at Austin, these beds are entirely missing, a fact which may be explained in connection with certain changes of level accompanied by volcanic events which took place just after they were laid down, exposing them to denudation before the next division was deposited. No systematic study of these beds, as a whole, has yet been made, and the thickness is estimated from casual observations by the writer.

The Lower Cross Timbers region abounds in rich sandy soils, which have not been studied minutely. These support a vigorous timber growth—this structure being especially favorable for deep-rooted plants, and are specially adapted to fruit growing, as seen near Denison and Paris.

There is also considerable iron in the beds of the Lower Cross Timbers, as well as lignite. The latter is frequently discovered and mistaken for bituminous coal. It is doubtful whether either is in sufficient quantities for commercial use. The Cross Timbers are also in the line of the Central Texas artesian belt, and it is probable that in any portion of its area an artesian well sunk through the rock of the underlying Comanche series would find an abundant flow of water. These sands are also valuable for water-bearing purposes, and the wells along the margin of the minor Black Prairie area are supplied from them.

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* One of these, on Timber Creek, near Lewisville, in Denton County, occurred in association with lignite and cross-bedded sands, and was largely composed of marine shells, such as inhabit the brackish waters of estuarine and near-shore deposits, consisting of undetermined *Cerithiidæ*, *Neritina*, *Ostrea*, *Aguillaria cumminsi* (White), and other littoral species. From a well at Whitesboro, which was dug in the sharp sands of this division, I procured fish teeth (*Otodus*), an Ammonite (*Scaphites*), and indeterminate mollusks. Dr. B. F. Shumard discovered leaves of flowering trees in this formation, and reported the same in the proceedings of the St. Louis Academy of Science, Vol. 2, p. 140. He also correlated these sands with those of Kansas and Nebraska called the Dakota group, or No. 1 in Meek and Hayden's section. They are probably the same as the Arenaceous group of Dr. Shumard's Texas section.

NO. 2. THE EAGLE FORD CLAY SHALES.

These lie to the eastward and immediately above the Lower Cross Timber sands, and are the foundation of the minor Black Prairie streak.

Beneath the scarp of the white rock (Austin-Dallas chalk) at Dallas, and extending westward through the Mountain Creek country to the Lower Cross Timbers, can be seen typical localities of this division, the thickness of which I estimate at 400 feet. These clays in their medial portion are dark blue and shaly, highly laminated, and occasionally accompanied by gigantic nodular septariæ, locally called turtles. The uppermost beds gradually become more calcareous, gradating rather sharply into the chalk. There are also occasional bands of thin impure limestones, which are readily distinguishable from all other Upper Cretaceous limestone by their firmness and lamination. Fossil remains of marine animals are also found in these clays, including many beautifully preserved species, the delicate color and nacre of the shells being as fresh as when the animals inhabited them.*

At Austin these beds occur in less thickness, and at one place—where Tenth Street crosses Shoal Creek—they are entirely missing, the chalk resting upon the Shoal Creek limestone. The northwestern part of the city is underlaid by these clays, which are here more calcareous and accompanied by beds of laminated limestone. South of the river, along the International Railroad, they are finely displayed in Bouldin Creek, with the characteristic blue color on fresh exposure. They also appear at San Antonio, near the cement works there, and at New Braunfels, and other intermediate points. North of Waco they increase in extent and thickness, forming extensive black waxy areas in Hill, Johnson, Ellis, Dallas, Collin, Lamar, Fannin, and Grayson counties, west of the white rock scarp.

The chief economic value of the minor Black Prairie will ever be its magnificent black calcareous clayey soil, while some of the chief geological considerations are the ascertainment of means to make this soil more easily handled and less tenacious by devising suitable mixtures, the discovery of road-making material, and the increase of water for domestic and agricultural purposes. Owing to its clay foundation the soil now retains for plant use treble the quantity of moisture of some of its adjacent sandy districts, but surface and flowing water is scarce. Fortunately, however, this district is also within the Central Texas artesian well area, and an abundant supply of water can always be obtained at a depth of less than 1500 feet, as has been proved in the course of our investigations. When this fact is fully appreciated the region will be one of the most prosperous in Texas. In the valleys

*Oysters, fish teeth, chambered shells (*Scaphites*, *Hoplites*, and *Acanthoceras*), and *Inocerami*, are most abundant.

of most of the streams running eastward across the east half of the minor Black Prairie, artesian water can be obtained at from one hundred to three hundred feet. The source of this water is in the Lower Cross Timber sand. Many of the concretions and calcareous layers are probably suitable for making cement, but tests must be made. The clays may also prove of commercial value.

The medial and lower portions of these shales are at places bituminous, as at Austin, Fiskville, and other places, and frequently an appreciable amount of rock oil appears upon the surface of the waters obtained from them, but so far there have been no reasons to justify any expectations that this oil occurs in commercial quantities, the indications being rather against such a conclusion.

NO. 3. THE WHITE ROCK, OR AUSTIN-DALLAS CHALK.

Immediately above and to the east of the Eagle Ford clays comes the white rock or Austin-Dallas chalk, which is the most conspicuous representative division of the whole Upper Cretaceous system. This occupies the narrow strip, as noted in the preceding topographic description, marking the western border of the main Black Prairie region, separating it from the minor Black Prairie. The outcrop of this chalk begins in the southwest corner of the State of Arkansas, and in the Indian Territory. It crosses Red River, the exposure continuing westward up the south side of the valley of that stream to the north of Sherman, from which place it deflects southward, passing near McKinney, Dallas, Waxahachie, Hillsboro, Waco, Belton, Austin, New Braunfels, San Antonio, and Spofford Junction, beyond which it bends northward, appearing in the disturbed mountains in the vicinity of El Paso and New Mexico. It is distinguished above all by its peculiar chalky substructure.*

The rock of this formation is a massive, nearly pure, white chalk, usually

*The words "limestone" and "chalk" are used in these pages as follows: Limestone is employed generically for species of widely different origin and structure. Specifically they may be of five kinds: 1. Breccias composed of more or less comminuted and cemented shells of ancient ocean bottoms or shores. 2. Concretions or segregations formed by the segregation of lime in clays and sands after original deposition—rare in our rocks. 3. Chalks are composed of amorphous calcium carbonate, usually more or less foraminiferal, void of laminations, and of comparative deep sea (not abyssal) origin. These may be hardened by metamorphism into firm limestones; hence the term chalky limestone will imply chalky origin, and the term chalk present chalky condition. 4. Laminated, impure limestones, occurring as alternating beds in sands and clays, indicative of shallower origin than chalk. 5. Metamorphosed limestones, or any of the above which have undergone induration or secondary change. All laminated limestones thus far found in the Texas Cretaceous are in the Basal beds, and are more or less arenaceous or argillaceous, further proving their origin to have been in shallower water than those in which chalk is laid down.

free from grit, and easily carved with a pocket knife. Under the microscope it exhibits a few calcite crystals, particles of amorphous calcite, and innumerable shells of foraminiferæ. The air-dried indurated surfaces are white, but the saturated subterranean mass has a bluish-white color. The rock weathers in large conchoidal flakes, with an earthy fracture.

In composition it varies from 85 to 94 per cent of calcium carbonate, the residue consisting of magnesia, silica, and a small percentage of ferric oxide, as can be seen from the following analyses of unselected specimens:

	Texas.	Rocky Comfort.
Calcium carbonate	82.512	88.48
Silica and insoluble silicates	11.451	9.77
Ferric oxide and alumina	3.648	1.25
Magnesia	1.189	trace.

The thickness of this chalk is about 500 feet. So far as observed in Texas it averages the same thickness at Austin, Sherman, and Dallas. It is of great uniformity throughout its extent, but there are a few local differences in hardness, which are sometimes due to surface induration and to igneous action, having been converted into marble at Pilot Knob, south of Austin.

In the vicinity of Austin the soft and chalky structure is somewhat destroyed by the volcanic disturbances of the vicinity, such as the co-deposition of volcanic ash, and excessive jointing and faulting, but it maintains its pure chalky aspect elsewhere.

A great portion of the former extent of this chalk has been destroyed by erosion, and its western border in Central Texas is now receding eastward under the influence of excessive atmospheric decomposition and denudation. From Austin to San Antonio it is more stable, but west of the latter place erosion again becomes great. That the whole group may once have extended far to the west, and perhaps entirely across the State, is not at all improbable.

It so resembles some of the beds of the underlying Comanche and of the overlying Upper Cretaceous that until recently they have not been differentiated. Upon close examination, however, it is noticeable that the Lower Cretaceous beds are distinctly stratified and very much harder and generally more or less crystallized from pressure, solution, and redeposition of the carbonate of lime in the chalk. The topography of the white rock beds is also of a milder type than that of the Comanche series, and is recognizable even at a distance. Above all, it is distinguished by its softness and by its entirely different fossil remains. They are also distinguished from the other chalky beds of the Upper Cretaceous by their greater firmness, different fossils, and by their higher percentage of calcium carbonate. With the exception of the White Cliff chalk of Arkansas, the other beds of the Upper

Cretaceous seldom contain more than 50 per cent of calcium carbonate, the average being 20 to 40 per cent.

The "white rock," or Austin chalk, abounds in fossils, most of which, however, are but poorly preserved casts.*

The economic advantages of the "white rock," or Austin chalk, are various. It affords good locations for the building of cities and communities, not only on account of the firm foundation for building and road beds and good drainage which it always affords, but on account of its sanitary conditions, produced by the imbibing capacity of the chalk. When accurate statistics are kept, it will be proved that dwellers upon the chalky lands have a great hygienic advantage over those upon sands and clays. The chalks are also water bearing, and while yielding their moisture slowly, they afford an abundance for domestic purposes, and play an important part in the transmission of the rainfall to depths from which it can be abstracted, perhaps, in East Texas, by artesian wells. The chalk is also valuable for the manufacture of whiting, rouge, etc. Chalk is most used in England, however, where scientific agriculture has attained its highest development, for dressing lands. Thousands of tons are used annually on the non-calcareous lands of England, where it is usually applied at the rate of twenty tons per acre, just as it will ultimately be used upon the non-calcareous lands of East Texas, as soon as our agriculture advances to a stage where its necessity will be appreciated. Chalk makes a cheap, convenient land dressing for non-chalky lands, performing in a more satisfactory manner the functions of quick-lime in making available other constituents of the soil and humus, besides contributing to it minute but valuable proportions of phosphates, potash, and other plant foods.

The chalk will also prove of great use in the manufacture of Portland cements. Chalk is the material used in the manufacture of most of the imported cement, and when the people of our State properly appreciate what an immense industry lies at their doors—a natural Texas monopoly—this region will become a great cement center for the United States.

NO. 4. THE EXOGYRA PONDEROSA MARLS.†

The eastward continuation of the Austin-Dallas chalk is covered by what

*The most characteristic species are *Hemiaster texanus*, Rœmer, *Ammonites* (*Mortoniceras*) *texanus*, Rœmer, *Terebratella guadalupæ*, Rœmer, and *Ammonites dentato-carinatus*, Rœmer. The most abundant fossils, however, are genera which range upward into the Ponderosa marls, including the numerous moulds of *Inocerami* and great masses of the young forms of *Exogyra ponderosa*, Rœmer. *Baculites*, *Pecten*, and many other Upper Cretaceous species are plentiful.

† The name given these marls is taken from the large fossil oyster, called *Exogyra ponderosa* by Dr. Rœmer, which occurs in immense quantities in certain beds.

is the most extensive and valuable, but least appreciated, geological formation in the United States—a remarkable deposit of chalky clays, aggregating some twelve hundred feet in thickness, according to reported well borings and estimates of the normal dip. In fact these clays are so little known that no popular name has been found for them, and hence they are called after the immense fossil oyster which is found in them. These clays occupy the whole of the main Black Prairie region east of the Austin-Dallas chalk, and form the basis of the rich black waxy soil. Notwithstanding their areal extent, good outcrops of the unaltered structure are seldom seen, owing to their rapid disintegration. Usually they are seen only in ravines, creeks, or fresh diggings. However, at the Blue Bluffs of the Colorado, six miles east of Austin, a good exposure is afforded, where these clays can be readily studied and diagnosed. They are of a fine consistency, unconsolidated, and apparently unlaminated until exposed to weathering, when their laminated character is developed. They are light blue before atmospheric exposure, but rapidly change into a dull yellow, owing to the oxidation of the contained pyrites of iron. Their chief accessory constituent is lime in a chalky condition, and they are more calcareous at their base than at the top. Near the top of these and other exposures there is to be seen a rapid transition into the black calcareous clay soil, characteristic of chalk and chalky clays, whenever their excess of lime comes in contact with vegetation.

The minute details of these clays have not yet been ascertained, and from the nature of the problem it is not evident that they can be discovered speedily; but it is apparent that they are more calcareous and fossiliferous at their base, where they probably gradate into the Austin chalk. Their middle portion is apparently void of well preserved fossils, yet impressions are abundant in places. Toward the top, as seen one mile north of Webberville, ten miles east of Austin, they become slightly arenaceous and concretionary and very fossiliferous, indicating a gradation into the Glauconitic division. The fauna of these concretionary clays at Webberville, Corsicana, and elsewhere begins to partake of the character of that of the Glauconitic division, and yield an abundance of species.

Although not the top of the series, the Webberville beds are its uppermost exposures seen along the Colorado River section, for at that place they are overlaid by the Lignitic or Basal division of the Eocene Tertiary. To the northward these beds thicken.

The economic value of these chalky clay marls is in that they are the foundation and source of the rich soil of the main Black Waxy Prairie of Texas, the largest continuous area of residual agricultural soil in the United States, apparently inexhaustible in fertility; for as the farmer plows deeper and deeper he constantly turns to light the fertile marls which renew the vitality.

To suppose that these soils can not be improved by further geologic study, however, is a great mistake.

NO. 5. THE UPPER ARENACEOUS, OR GLAUCONITIC, DIVISION.

In East Texas along the eastern margin of the Black Prairie region, and in Southwest Arkansas—which is but the northeastern termination of the Texas section—where the rivers have cut through these overlying Tertiary beds, the uppermost beds of the Black Prairie series are glauconitic and arenaceous. This division is the upper continuation of the Ponderosa marls, its chief difference being that the clays gradate into sands and glauconite as we ascend, and there are conspicuous changes in the fossils, which become more plentiful, and the species partake of the same faunal characteristics that distinguish the Cretaceous of the New Jersey and Alabama regions. This division as it occurs in Southwest Arkansas has been minutely described in my Arkansas report, but its whole detail remains to be developed in Texas, its occurrence having only been affirmed in one or two places without specific detailed study.*

In the extreme northeastern counties of the Cretaceous area these greensand beds are more abundant, and investigations into their details are now being conducted.

Like the main Black Waxy Prairie lands, from which they are hardly distinguishable, they are fine agricultural lands, possessing an advantage in being less sticky and tenacious. The glauconite, or greensand, will no doubt be found in greater and purer quantities in some localities than in others, and will prove of great local value as a fertilizer. In New Jersey similar marls are used to the amount of $2,000,000 worth per annum, and immense tracts of previously supposed poor lands, similar to some which exist in great quantities in our own State, have been reclaimed and converted by their use into fertile fruit and vegetable regions.

II. THE LOWER, OR COMANCHE, SERIES.

THE FORT WORTH, OR GRAND PRAIRIE.

The name prairie covers a multitude of diverse geographic features in Texas, of which the absence of timber growth is, to the casual observer, the most conspicuous; and hence the fact that west of the Black Prairie region (and its basal Lower Cross Timbers) there is another entirely distinct geographic and geologic region, which, until recently, has been confused with it. This is the beautiful prairie country surrounding the city of Fort Worth

*The Neozoic Geology of Southwestern Arkansas. Second Annual Report of the State Geologist, Little Rock, 1889.

which lies between the Cross Timbers. It is the so-called "mountain country" in western Williamson, Travis, Hays, Comal, and other counties of the southwest, as it extends across the State immediately west of and parallel to the Black Prairie region. South of Austin the edge of this plain, which forms an eastwardly facing escarpment, is known as the Balcones. North of the Brazos the Balcones scarp disappears and the narrow forest region of the Lower Cross Timbers marks the eastern border of the Grand Prairie.

The east and west railroads between Whitesboro and St. Jo, between Fort Worth and Weatherford, Fort Worth and Decatur, Fort Worth and Granbury, Waco and DeLeon, Belton and Brownwood, McNeil and Burnet, and San Antonio and Kerrville, all cross the characteristic Grand Prairie.

Upon closer study it will be readily seen that it differs in nearly every physical feature from the latter region. In general it is more elevated, its plateaus are nearly level instead of undulating, its valleys more precipitate, and the valleys benched and terraced through the unequal resistance and varying hardness of its alternate stratification. Its soils, except in valleys, are generally shallow and rocky, while their color tends to yellow and chocolate browns instead of black. The chief difference, however, is in the underlying rocks, which are the foundation of all the above features. These compose a beautiful substructure, whose hundreds of feet of white chalk and yellow magnesian layers of alternating degrees of hardness, gave to the landscape a unique tone and topography not found elsewhere in America. The western border of this region is carved into a rugged scarp, accompanied by outliers of terraced buttes and mesas.

At the base of this western margin in most places can be found a more or less narrow sandy district of timbered country, like the Upper Cross Timbers of Northern Texas, which is the areal outcrop of the lowest rocks composing the series underlying the Grand Prairie.

The rocks of the Grand Prairie region are as yet as little known in literature, as its geography, because until recently they have always been confused with those of the Black Prairie region or Upper Cretaceous series. It has been shown,* however, that the Black Prairie is the uppermost of two distinct Cretaceous formations of the United States, and that those underlying the Grand Prairie region constitute a distinct and lower series of rocks, of even greater thickness, to which I have given the name of Comanche series, out of deference to the town of Comanche, where I first studied them. The rocks of the Black and Grand prairies represent two distinct subsidences, between which there was a land epoch of long duration. In general the Co-

*The first announcement of this series was published by me in the American Journal of Science, January, 1887, p. 75. See Record of Science, for 1886, Smithsonian Report, 1887-8, p. 220.

manche series consist of from 1000 to 2000 feet or more of predominatingly calcareous (chalky) rocks, sometimes argillaceous and arenaceous, as shown in the section beyond, arranged in almost horizontal layers, of varying degrees of hardness, and great uniformity in extent. They usually incline coastward; in places are considerably jointed and faulted. Its rocks, like those of the Upper series, from bottom to top record a complete ternary succession of strata, to-wit: 1. A lower stage of sandstones, shales, and other sedimentary deposits, representing prevalence of land with downward movement. 2. A middle stage, chiefly of limestone, representing prevalence of sea, and general quiescence and elaboration of calcareous organic formations. 3. An upper stage, and more of mechanical sediments, indicative of proximity to land.

The whole Comanche series is thus divided into three grand divisions, to-wit, the Trinity or Basal (sandy beds), the Fredericksburg or Medial (chiefly chalky beds), and the Washita or Upper division (impurer chalks and clays, alternating in stratification, becoming slightly arenaceous in the Denison region, but not so at Austin, for reasons explained later).

NO. 1. THE TRINITY SANDS OR UPPER CROSS TIMBERS DIVISION.

TRAVIS PEAK SANDS, OR WATER-BEARING BEDS.

In every place where the base of the Comanche series has been seen it has had the coarse sedimental characteristics of a near-shore formation, gradating upward into finer and deeper sea deposits. The eastern edge of the Upper Cross Timbers is a good illustration of the beds. In the Colorado section, near the Burnet-Travis county line, this division is essentially arenaceous in composition, clastic in structure, and composed at its base of conglomerates or sands, the origin of every pebble of which can be located in the adjacent and more ancient strata of the Paleozoic region. In the southeastern edge of Burnet county the Trinity sands are in contact with the Paleozoic schists, limestones, sandstones, and pre-Trinity granites. Succeeding the basal conglomerates is a coarse, angular, cross-bedded sand, which becomes finer and finer until it reaches the condition known in Texas as "pack sand," i. e., a very fine grained sand, which is cemented by included chemically precipitated calcium carbonate. Fossils have been found by the writer at Sycamore Creek, Burnet County, in the contact conglomerates, but they are neither plentiful nor distinct until the upper or pack sand beds are reached, one mile below Travis Peak postoffice, where the arenaceous layers are full of casts and moulds.*

In this vicinity, also, appears the first of the several conspicuous oyster

*These consist of undetermined *Trigonias*, *Pholadomyas*, *Cyrenas*, and an undescribed *Ammonite* resembling *Hoplites dispar*.

beds of the Comanche series. This is composed of a solidified mass of large grypheate oyster shells resembling the dilate species figured by Marcou as *Gryphæa dilatata*, but not yet positively determined. These were found to form a stratum seven or eight feet in thickness, just below the junction of Post Oak and Cow Creeks. Accompanying the Gryphæa breccia there is also the first appearance of another conspicuous feature in the Comanche series, i. e., an excess of epsom salts, or magnesian sulphate. The oyster shells are being rapidly cemented into massive limestone beds, or decomposing into a powdered earthy substance accompanied by incrustations of epsom salts (epsomite). This magnesian feature, which becomes more conspicuous higher in the series, is a fine illustration of an instance of the conversion of a shell limestone into dolomite by an alteration subsequent to the formation of the original rock, as has been recorded by Irish geologists.*

In places throughout the sands are occasional patches of red and greenish-white clays, resembling very much the characteristic features of the red beds of the lower formations, sometimes accompanied by lignite and fossil bones. The cause of these discolorations has not been studied. There are from 200 to 300 feet of these arenaceous Trinity beds in the Colorado section, at the top of which appears a fossiliferous horizon—the first or lowest appearance of *Monopleura* (*Caprotina*) and *Requienia*—which we assume to be the beginning of the second division of the Comanche series. Thus the Trinity beds in the Colorado section are seen to be composed of locally derived debris, which, as the waters deepened, became more and more comminuted and calcareous, until the sand grains at the top are almost imperceptible to the eye, and the whole mass becomes quite chalky and magnesian in appearance. As shown elsewhere, these basal arenaceous beds everywhere vary with the shore line upon which they were laid down, and are different in composition and detail in the Brazos and Arkansas sections.

Economic Use of the Trinity Sand. — Notwithstanding its sterility of soils, it is no exaggeration to say that they constitute one of the most valuable rock sheets in the State, inasmuch as their porous beds, dipping between two impervious strata to the eastward, constitute a ready medium for the percolation and transportation of most of the water that falls upon them to greater depths, where from a lower surface altitude than their outcrop they are penetrated by artesian wells drilled from above, and bountifully supply the artesian water now being secured all along the country adjacent to the margins of the Black and Grand prairies at Fort Worth, Taylor, Waco, Austin, and other places from Red River to the Rio Grande. Thus it is that a stratum which outcrops in one region as a sterile sandy district, in reality proves a

*See Prestwich's "Geology, Chemical, Physical and Stratigraphical," Vol. 1, pp. 113, 114.

fountain of inestimable value to another region beneath which it lies concealed and usually unappreciated.

Wherever the surface outcrop of these sands has attained any areal extent, they are covered with a comparatively abundant scrubby forest growth, as conspicuously illustrated in the case of the Upper Cross Timbers. The sandy soils resulting from their disintegration, however, are not as rich in fertilizing ingredients as the overlying calcareous soils, but they can be greatly improved by mixtures. The soils, as indicated by their natural vegetation, are the best adapted to tree growth, and are becoming the seat of a fruit growing industry.

The lignites and occasional iron ores in the Trinity sands are worthless, and the alleged gold discoveries existing in nearly every neighborhood invariably turn out to be iron pyrites.

NO. 2. THE FREDERICKSBURG DIVISION.*

In the high bluffs of Cow Creek, in the western edge of Travis county, immediately below Mr. Hensel's house, at Travis Peak postoffice, the Trinity sands can be seen gradating upwards into this division, the lowest beds of which are marked by the appearance of certain magnesian sandy marls and rocks, accompanied by the presence of certain fossils, which we have called the Caprotina Horizon No. 1. According to our classification in the general section given beyond, this is the base of the Fredericksburg division, and is principally composed of calcareous matter with apparently equal parts of fine quartz sand and magnesia, in bands or strata of alternating degrees of consolidation. Although showing a deeper and more uniform sedimentation than the Trinity sands, yet, as shown by the alternating sediments, the chalky, deepest sea, conditions of the Comanche Peak beds have not yet been reached. The alternation of harder and softer layers of arenaceous-calcareous strata prevails, and the beds become thicker and more massive as the ocean's bottom descended. Such is the beginning of the beds to which I have applied the name of the Fredericksburg division, which may be divided into three lithologic subdivisions, to-wit:

(c) The Caprina Chalky Limestone Beds.
(b) The Comanche Peak Chalk Beds.
(a) The Basal or Alternating Beds.

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* This division is named after the town of Fredericksburg, whose vicinity was visited by Dr. Ferdinand Rœmer, now Professor at Breslau, Germany, forty-five years ago (1845–1847). This gentleman, who might be termed the pioneer of Texas geologic investigation, described many of the unique fossil remains of the rocks which we now place in this division.

2*a*. THE BASAL OR ALTERNATING BEDS.*

The basal beds consist of thin arenaceous white limestones of a coarse, crystalline, and chalky aspect, sometimes slightly brecciated, but seldom exceeding one or two feet in thickness and of great uniformity in extent of stratification. These beds are separated by softer unconsolidated, magnesian, slightly argillaceous marls, resembling the yellow marls of France as I understand them to be, and often of oolitic structure.

This alternation of softer marls and harder limestones produces the beautiful bench and terrace topography of the western scarp of the Grand Prairie south of the Brazos River and east of the coal measures, which is especially well shown in Burnet County, southeast of Burnet, in western Travis, and numerous other places. They seem to be missing, however, in the northwest. While more or less very finely arenaceous and calcareous at the base, the quantity of sand in the mixed strata gradually diminishes upward, and the chalky lime increases until the culmination of the chalky bed recorded in the next division. The yellow magnesian strata also increase in thickness, and become very conspicuous in the middle portion of this lower subdivision often being from five to fifteen feet in thickness, as seen in the bluffs of Mount Bonnell north of the great fault. These magnesian limestones are soft enough to be cut with a knife, and are of a brownish yellow color. They alternate with similar strata of chalky limestones and yellow marls. The upper 100 feet of the basal subdivision of the Fredericksburg division, as seen at the top of Mount Bonnell, again present the unique stratification of the basal beds, the lime strata averaging about one foot in thickness.

The intervening yellow magnesian marls are soft and laminated, more or less siliceous, and composed of minute shells and concretions, which make it distinctly oolitic in character, and hence I propose for this stratigraphic horizon the name oolitic marls.† These marls have very little clay, and pack when wet like fuller's earth. When properly understood they promise much, both from an economic and purely scientific standpoint.

They finally terminate in persistent beds of yellow marl abounding in a beautiful oyster, after which it is called the culminating horizon of *Exogyra texana*. From careful measurements of Mr. J. A. Taff, at Travis Peak, from

*Nos. 4 to 17 of the detailed section of Shovel Mountain, Burnet County, published by Dr. B. F. Shumard in the Transactions of the Academy of Science, St. Louis, Vol. 1, pp. 584 and 585, 1860, are typical of these alternating beds.

† The term oolitic is here used after Prestwich's definition, to-wit: "A compact light yellow and gray carbonate of lime, often in the form of small rounded grains like the roe of a fish, at other times consisting of small comminuted fragments of shells." (Prestwich's Geology, Chemical, Physical, and Stratigraphical, Vol. 1, p. 20.)

the basal Caprotina horizon to the culminating horizon of *E. texana* inclusive is a height of 406 feet.* The beds of magnesian limestone which mark the central third of this division are especially worthy of future study and observation from a petrographic and chemical standpoint. They are sometimes accompanied by pockets of calcite, aragonite, celestite, and epsomite, as near the summit of Mount Bonnel, near Austin This basal subdivision of the Fredericksburg division is not well known in the northwestern portion of the State, but apparently diminishes in importance in that direction, being only about 100 feet thick in Comanche County, but maintaining considerable thickness at Comanche Peak, Hood County, 100 miles northeastward.

Economic Features of the Basal, or Alternating, Beds.—While the basal Fredericksburg division no doubt possesses many valuable qualities as a source of building material, and many mineral substances, as an agricultural region, it is practically sterile, as can be readily seen in the so called mountain slopes of western Travis and eastern Burnet counties. In fact it does not even possess a favorable grazing region, except for goats and scrubby horses, the cattle being usually small and poor.

In the valleys of its creeks and streams small patches of soil have collected, which afford a meagre subsistence for a few farmers; but as these do not compose one per cent of the aggregate area, the fact remains that the alternating beds, from the present agricultural standpoint, remain valueless. What the application of the soil-saving methods of Europe and China may ultimately do for the same is not in our province to predict.

The reasons of this sterility are apparent. (1) *Chemical.* There is an excess of lime, sulphur, magnesia, and other salts in the rocks and waters, which are deleterious to vegetation and animal life. (2) *Physical.* The slopes are steep and prevent the accumulation of soil. (3) *Geological.* There is an absence of sufficient clays in the substructure to retain for the use of vegetation the moisture which this formation so readily imbibes, while the strata at the surface store a great amount of heat. These two geologic causes render the surface outcrop of these basal alternating beds far more drouthy than the adjacent regions, although possessing an equal amount of rainfall.

While void of any great agricultural possibilities, however, the basal, or alternating, beds, abound in useful material to mankind, and especially in

*Throughout the series fossils are occasionally found, especially *E. texana*, *Nerinea*, *Requienia* (*Caprotina*), *Cyphosoma*, and casts or moulds of *Tylostoma prægrandis*, Rœmer, *Arca*, *Trigonia*, and especially the peculiar globular foraminifera-like form which has been called *Goniolina?* by D'Orbigny. There are also horizons more or less chalky throughout, one of which is especially interesting in that it is a perfect mass of small coin-shaped foraminiferæ called *Orbitolina* (*Tinoporus*) *texana*, Rœm.

valuable building material, among which may be mentioned building stones of value for domestic uses and exportation. Some of these stones have rich magnesian buff-yellow colors, while the limestones often resemble in every detail the famed stone of Caen, France, which is imported into the non-chalky regions of the East for the purpose of adding brightness to the sombre colors. They are especially used in interiors, where the ease with which they can be carved renders them of great value.

The magnesian beds are also exceedingly valuable for the manufacture of hydraulic cements, although to-day they are unappreciated. There are also valuable beds of epsom salts, glauber salts, gypsum, strontianite, and other materials in these rocks, for all of which there is a commercial use in our civilization.

2*b*. THE COMANCHE PEAK SUBDIVISION.

Immediately above the *E. texana* beds the great series of alternations terminate in a massive persistent chalky division, marking, no doubt, the beginning of the culmination of the great subsidence of the sea bottom (as recorded in the succeeding Caprina chalk) which had been going on since the pre-Trinity land epoch. This subdivision is composed of white chalky limestone, which readily yields to disintegration, usually forming the sloping sides of buttes and mesas, and capped by the Caprina chalk, next to be described. It is characterized by its abundant fossil remains.*

The chalky beds of the Comanche Peak subdivision are the most extensive and uniform of the Comanche series, and must ever stand as the basis for comparison from which to estimate the relative value of the overlying and underlying horizons. It presents on weathering a sterile, rocky aspect, and is covered by sparse, stunted, coriaceous vegetation. An interesting fact concerning this subdivision is that several hundred feet above it, in the Washita limestone, its lithologic conditions and features are simulated, but modified as to species, only the *Neithea quadricostata*, Rœmer, and *Gryphæa pitcheri* running into the Washita division, and these presenting broad varietal changes. This lithologic repetition is no doubt due to the fact that after a time the descending ocean bottom again began to rise, and in so doing passed through the same conditions of depth, producing the same character of sedimentation.

* The especially characteristic species are a star fish (*Toxaster texanus*, Rœmer), and *Ammonites pedernalis*, Von Buch. At the base of the chalk there is usually another marked bed of Grypheate oysters (*G. pitcheri*, with *E. texana*), as seen near the summit of Mount Barker, in the Bonnell ridge, Round Mountain, Comanche County, and especially in the town of Weatherford, extending on to Red River. This is the second, in ascending order, of the great oyster beds of the Comanche series, and is composed of countless numbers of individual shells of *Gryphæa*, and is of marvelous areal extent.

The economic aspects of the Comanche Peak beds are mostly æsthetic. Their weathering adds beauty to the landscape, and the remnants of ancient marine life so abundantly preserved in it should afford abundant material for instruction to those who are capable of appreciating the grander features of the earth's history. The chalks, were they the only ones in our State, would perhaps be of great economic value for cement making and agricultural uses, and the remarks applied to the Austin chalk, on page 114, are equally applicable to them.

2*c*. THE CAPRINA CHALK AND CHALKY LIMESTONE SUBDIVISION.

Without any observed stratigraphic break, the Comanche Peak chalk gradates into 300 feet, more or less, of chalks and chalky limestones of varying degrees of consistency, from a pulverulent condition to firm limestones, which seem to be a secondary condition of the chalk produced by superficial hardening. These hard layers form the cap-rock of the buttes and mesas or highlands of the extensive Grand Prairie region, and are the cause of the flat topped topography of the so called mountains of Central Texas. They usually occur at an altitude above 1000 feet along the margins of their eastern outcrop, but at Austin they have been broken along the line of their strike by a great fault, and as a result the eastern side has fallen down from 1500 to 750 feet above sea level, as exposed in the river bluffs between Austin and Mount Bonnell, on the Colorado, where the chalk has been more or less hardened into firm limestones by the local metamophism accompanying faulting.

In these chalks and chalky limestones are well defined layers of exquisite flint nodules, occupying apparently persistent horizons in localities. These flint nodules are oval and kidney-shaped, ranging in size from that of a walnut to about two feet in diameter. Exteriorly they are chalky white, resembling in general character the flint nodules of the English chalk cliffs. Interiorly they are of various shades of color, from light opalescent to black, sometimes showing a banded structure. These flint nodules are beautifully displayed *in situ* in the Deep Eddy canyon of the Colorado, above Austin, where they can be seen occupying three distinct belts in the white chalky limestones.

Where these chalky limestones form the mesas of rapidly weathering plateaus, such as the remnants of the Grand Prairie west and southwest of Austin, the flints are left in great quantities as a residuum (the softer chalks being more readily decomposed into soils and washed away), and they cover large areas of country. They have also been transported eastward in past geologic times by marine and river action, and are distributed over large areas along the margin of the Black Prairie region as a part of the Post-Cre-

MAGNESIAN BEDS OF MOUNT BONNEL.

Showing Celestite Pockets and Valley of the Colorado River through Grand Prairie.

taceous gravels of that region. In some of these flints remarkable decomposition is exhibited, the product being geode-like cavities lined with quartz crystals and pulverulent material. In one instance an apparently unaltered specimen picked up *in situ*, upon being broken open revealed a small cavity filled with a liquid inclusion. Occasionally the flints, especially an opalescent variety in Comanche County, possess nuclei in the shape of fossils, usually the *Requienia* (*Caprotina*).

The fact that these are the only flint horizons, so far at least as is known to the writer, in the whole of the immense Cretaceous deposits of the United States, is very interesting, and especially since they occur about the middle of the Lower Cretaceous series instead of at the top of the Upper series, as in England. It was from them that the Indians made most of their flint implements, and the ease of their lithologic identity will be of value to the anthropologist in tracing the extent of the intercourse and depredations of former Indian tribes inhabiting this region.

The decomposition of these flints and of the adjacent limestones has produced some peculiar and unique effects in the rocks and landscape of the region, the silica replacing the calcium carbonate and leaving as a remnant a peculiar porous, cavernous rock, usually of a deep red color from the hydration of the iron pyrites into limonite, composed of the siliceous pseudomorphs of fossil *Rudistes*, *Hippurites* (rare), and other shells, the interstitial spaces glittering with minute quartz crystals which line them. This red rock is co-extensive with the areal outcrop of the Caprina limestone.

Immediately west of Austin, along the downthrow of the great Bonnell fault in the bluffs of the Colorado, occasional red decomposing spots occur in the crumpled and faulted strata of the massive white chalky limestones. Upon closer examination the apparently non-fossiliferous limestone is seen to be undergoing decomposition into a dry pulverulent inflorescence, and as a residuum there remains a dry red dust and exquisitely preserved calcite pseudomorphs of many rare fossils, such as recently described by Rœmer* and White,† the occurrence of which I have located in this horizon.

The thorough investigation of these important and peculiar phenomena may prove of great economic value, as traces of the following important economic products have already been discovered by a few tests: Potash, salt, strontianite, anhydrite, epsom salts, gypsum, and gold, but in quantities as yet unknown. These inflorescences are coincident with the fault lines adjacent to the ancient volcanic disturbance of Pilot Knob. The chalky deposit of the

* Ueber einer durch die Heufigkeit Hippuriten Artiger Chamiden ausgezeichnet Fauna, der oberturonen Kreide von Texas. Paleontologische Abhandlungen, vierter band, heft 4. Berlin, 1888.

† Bulletin No. 4, U. S. Geol. Survey, Washington, 1887.

Caprina limestone is no doubt the continuation and culmination of the great subsidence of the ocean's bottom in Lower Cretaceous time, and will be of service in future interpretation and final correlation. It is very uniform, and covers large areas of the Grand Prairie plateau in southwest Texas, especially in the region adjacent to the lower Pecos. It also caps the mesas of the remnantal areas in the Abilene country, and as far east as Comanche Peak in Hood County. The railroad from Brueggerhoff to McNeil along the Williamson-Travis County line crosses a typical portion of its strike.

Economics of the Caprina Limestone.—The Caprina limestone is also productive of many rare building stones and other structural material, while the immense flint deposits will no doubt be ultimately utilized.*

The Caprina limestone is the material used in the manufacture of the Austin lime, which has a wide celebrity for its purity. This stone also makes a good material for macadamizing roads, and is now being extensively used for that purpose by the city of Waco.

The residue of the Caprina limestone and certain marly beds at the top† make the richest and most productive agricultural soil of the Grand Prairie region. It is readily distinguished by its dark red, sometimes nearly black, color, as seen in the country between Florence, Williamson County, and Leander, and in the Jollyville neighborhood of Travis County. It also occurs in Bell, Coryell, Hamilton, Bosque, and Hood Counties. This soil has not yet been mapped or classified.

No. 3. THE WASHITA DIVISION.

The Caprina chalky limestones which mark the culmination of subsidence in the Comanche series are succeeded by deposits of a lithologic and stratigraphic character which indicate that the ocean's bottom had reached the culmination of the long subsidence which it had been undergoing since the beginning of the Trinity beds, and had commenced the gradual elevation which finally terminated in the Mid-Cretaceous land. This shallowing is well illustrated in the thin stratification of the rocks above the Caprina limestone, to which the name Washita Division has been given, after the region where its rocks were first seen by early explorers near Fort Washita, I. T.

*The Caprina limestone was given its name by Dr. B. F. Shumard from the abundance of the peculiar aberrant fossils of the genus *Rudistes* (which have been described as *Requienia*, *Caprina*, *Monopleura*, *Ichthyosarcolithes*, etc.) occurring in it. These peculiar forms are found occasionally in great masses. Accompanying these beds are also many new and undescribed species.

†These beds are characterized by the peculiar smooth-ribbed Ammonite *Schloenbachia peruvianus*, De Buch (*A. acuto-carinatus*, Rœmer). They have not been satisfactorily studied in the Colorado section as yet.

The Washita Division along the Colorado is composed of the following well marked subdivisions:

	Estimated Thickness.
The Shoal Creek Limestone	+ 80
The Exogyra Arietina Clays	— 80
The Washita or Fort Worth Limestone	+150
The Caprotina Beds	+ 20
The Flagstones	+ 10
Total thickness in feet	+340

Of these horizons only the Washita limestone and the *Exogyra arietina* clays are known to have any persistent extent, these being found as far north as the Arkansas-Choctaw line and southwest to the Pecos.

3a. THE FLAGSTONES.

These can be seen at McDonald's brickyard, Johnson's quarry, Taylor's lime kiln, and other points immediately west of Austin. They consist of thin flagstones, of almost pure white chalky limestone, varying from one to three inches in thickness, and are void of fossils.

The surfaces of the slabs, which are quarried for paving and building stone, are sometimes covered with the pentagonal markings usually attributed to mud cracks, and these are filled with soft yellow lime material. These beds are only eight or ten feet in thickness, and their occurrence elsewhere than in the Colorado section has not yet been reported.

3b. THE UPPER CAPROTINA LIMESTONE, OR AUSTIN MARBLE.

Immediately above the flagstones, along the line of the Bonnell fault, and in West Austin at nearly all the localities above mentioned, is a massive stratum of limestone often metamorphosed into marble, which is composed almost exclusively of the calcified shells of *Requienia* (*Caprotina*), *Nerinea*, etc., accompanied by occasional *Hippurites*. This horizon was confused by Dr. B. F. Shumard with the Caprotina horizon some 1000 feet below, which marks the beginning of the Fredericksburg division. Away from the metamorphism of the Bonnell fault and local igneous action, the bed has not the crystalline consistency of marble. This bed is interesting, inasmuch as it represents the final appearance of the more or less continuous *Requienia* fauna which outcrops at various places from the bottom to the top of the Fredericksburg division, and it is possible that this horizon may in reality represent the close of that division. Between the Caprotina limestone and the Flagstone horizon there are beds of yellow laminated calcareous marls of a few feet in thickness, with the latest known horizon of *E. texana* and

a peculiar *Panopœa.* This limestone has been extensively quarried for building stone, and can be seen in the foundation of the postoffice building at Austin. It also receives a handsome polish, and has been used for ornamental purposes.

THE WASHITA OR FORT WORTH LIMESTONE.

Resting upon the upper Caprotina limestone (whether comformably or not has not been determined) commences the Washita limestone—one of the most important beds of the Comanche series. This consists of a comparatively massive, chalky, fossiliferous limestone. The base and top are compact and the middle more disintegrated. It consists of impure chalky limestones, shell breccia, and calcareous marls in alternating strata, having the same general aspect upon weathering as the Comanche Peak beds. Lithologically it seems to represent a similar depth of deposition.*

In its upper beds, however, the Washita or Fort Worth limestone, especially in North Texas, begins to show shallower conditions. At Austin, as can be seen in the railroad cut west of the city, it terminates in a comparatively massive lime stratum with numerous individuals of the only *Brachiopod* species thus far discovered in the Lower Cretaceous series of Texas, to-wit, *Terebratula wacoensis*, Rœm. The fossils in the Washita limestone show a tendency to occur in zones, which persist over vast areas, and about the same species characterize each zone wherever the writer has observed them. These limestones are well exposed at Salado and Fort Worth, the latter city being situated directly upon them. They contain more clay in the intervening layers in the latter vicinity, however.

THE EXOGYRA ARIETINA CLAYS.

In Shoal Creek, at Barton Springs, near Round Rock, and other places in the vicinity of Austin, the *Terebratula wacoensis* horizon of the Washita limestone is surmounted by about eighty feet of unctuous laminated clays of a greenish blue color previous to long exposure to the elements, and dirty yellow afterwards. The lower half of these clays is filled with the small unique *Exogyra arietina* or ram's horn oyster, which occurs in no other known horizon in the world. There is no transition between these clays

* Accompanying this return of conditions is an excessive abundance of life of great generic resemblance to the Comanche Peak fauna, but, with the exception of *Gryphœa pitcheri* and *Neithea texana*, of entirely different species. In place of the small *Toxaster texanus* of the Comanche Peak, we have the large *Macraster elegans*, Shumard, Rœmer; for the beautiful *Exogyra texana* there is substituted the similar but larger *E. sinuata;* while the *Ammonites leonensis* has superseded *A. pedernalis*. Here, too, the *Gryphœa pitcheri* (type, var.) breccia, with *E. texana*, has its duplicate in a breccia composed of *G. washitaensis* accompanied by *Ostrea carinata.*

and the including limestone horizons, but the Washita fauna again appears somewhat modified in the upper portion. At Austin, at the contact of these clays with the Shoal Creek limestone, is found the last horizon of *Gryphæa pitcheri*, Mort., which appears as the variety *navia*, but varying in shape and size, being characterized here chiefly by the thickness and size of its shell.

There are occasional segregations of the fossils into limestone, but these have no persistent extent or size. There are also numerous crystals of selenite, which are a product of the reaction of the decomposing iron sulphides (pyrites) upon the numerous oyster shells. These clay beds are worthy of closer study and definition than it has been possible to give them. Like the underlying Washita limestone, they have great geographic extent and uniformity. Their purity, extent, and apparent freedom from littoral debris make them easily distinguishable. The Arietina clays produce a black waxy residual soil, the only truly black soil of the Comanche series, the others being chocolate black or other dull colors. I have seen them only in Travis and Williamson counties.

THE SHOAL CREEK LIMESTONE.

In the western portion of the city of Austin, forming the rocky walls of the Shoal Creek Canyon, and for a few miles north and south, the uppermost strata of the Comanche series consist of beds of a peculiar crumbly limestone. This limestone is from forty to eighty feet thick, and of a yellow color, with many spots of red and pink.

It is stratified, and upon close examination it is seen to be made up of minute fragments of shell, which are rapidly losing their integrity by alteration either into a harder condition or by breaking down into a pulverulent powder, as in the case of the Caprina limestone before described. The red blotches have been attributed to several causes, to-wit: (1) The decomposition of iron pyrites; (2) the oxidation by heating of adjacent igneous material; and (3) the decomposition of contained volcanic ash and cinder which were deposited contemporaneously with it. This point has not been finally determined, however.

In places the Shoal Creek limestone is decomposing and crumbling, while everywhere it is much jointed and faulted. The fossils contained therein are interesting, but have been as yet but little studied. The top surface of this limestone has been corroded and waterworn, and deposited unconformably upon it can be seen the radically different sub-littoral unconsolidated clays of the basal Upper series.

This limestone makes a convenient building stone, but of no great commercial value. Its residual soil, like that of the Caprina limestone, is of a

rich dark red color, and covered with handsome timber growth, as seen at the Pease mansion in West Austin.

THE DENISON BEDS.

This abrupt termination of the Lower Cretaceous, together with the Shoal Creek limestone at Austin, is local, and, as will be shown later, due to the peculiar igneous disturbances that prevailed in this vicinity. To the northward, where these disturbing conditions were not present, the final termination of the Comanche series is quite different, as at Denison, for instance, where the Washita limestone, as seen one and one-fourth miles north of the city, is succeeded by shallowing alternations of clays and impure blue and yellow limestones containing an abundant littoral fauna, characterized by *Ostrea quadriplicata*, Shumard. The details of these beds, although reconnoitered once or twice, have not been accurately determined, but further field work will soon be undertaken in that region.

Dr. B. F. Shumard almost inextricably mixed his brother's results in his generalized section of Texas rocks.* The Denison beds abound in massive strata of an excellent, firm, semi-crystalline blue and yellow limestone, which is extensively used throughout North Texas for building purposes.

*B. F. Shumard: "Observations upon the Cretaceous Strata of Texas." Trans. Acad. Science of St. Louis, Vol. I. 1856–60.

STRATIGRAPHY OF THE COMANCHE SERIES IN GENERAL.

From the foregoing facts it is evident that the Comanche series possesses a well defined lithologic and stratigraphic history. Its lower division is essentially sandy, but becomes less and less so and more calcareous as the bottom upon which it was laid down subsided.

The lithology of the Comanche series is predominantly calcareous and is marked by several essentially chalky horizons. There are also magnesian and arenaceous beds, but these are modified in color and appearance by the predominance of the accessory chalky matter. In color the tint is chalk white, yellow, cream-colored, and occasionally the white rock weathers into a dark grey, and not even in a single case are these rocks concretionary as recently recorded, unless it is in a few feet of the Denison beds above mentioned.

Portions of the section are stratified into bands of one foot or more, but a large majority of the strata are massive, while the whole series, except a few alternating marls and layers of the Trinity, are remarkably free from lamination.

The alternating beds of the Basal subdivision of the Fredericksburg clearly show a deeper sea condition of origin than the Trinity, but not as deep as the chalk of the Comanche Peak and Caprina limestone subdivisions, which were deposited in very deep and quiet waters. After the latter there is a hiatus in our knowledge, but the Washita division reveals an elevation of the ocean's bottom as slow and positive as is the subsidence recorded in the other basal divisions. In brief, there is recorded (1) a long continued subsidence, during which nearly one thousand feet of deepening uniform sediments were laid down over vast areas; (2) a long continued deep sea condition, in which four or five hundred feet or more of chalks were deposited; (3) an elevation in which from three hundred to five hundred feet of shallowing sediments were deposited (the Washita division).

There can be but little doubt that the rocks now composing the Comanche series were elevated into dry land, that the succeeding land epoch continued probably as long as the time of deposition of either of the including series, and that the rocks of the Upper series were largely derived from the underlying Comanche strata, and laid down during an entirely different and later oceanic subsidence.

It is also evident that the Comanche series thickens to the southwestward and thins northward. Mr. Taff's measurements along the Colorado section make it 1500 feet, but both the top and basal beds are locally curtailed there.

Throughout its extent the rocks are jointed, and along their eastern margin greatly broken and faulted parallel to their strike, while occasional areas of igneous rocks protrude through the series southwest of Austin.

The foregoing rock sheets can be briefly summarized in a convenient table for reference as follows:

PROGRESS SECTION ILLUSTRATING THE CRETACEOUS SYSTEM OF TEXAS AS INVESTIGATED TO JANUARY 1, 1890.

B.

The Upper or Black Prairie Series.

DIVISIONS.	BEDS.	HORIZONS OF CHARACTERISTIC FOSSILS.	TYPICAL OCCURRENCE.
5. Glauconitic Division.		*Exogyra costatas.* *Ostrea vesicularis.* *O. larva.*	Mostly covered by tertiary overlap. Found in Anderson and Bowie counties. Most fully developed in Navarro and Kaufman counties.
4. Exogyra Ponderosa Marls, or Blue Bluffs Division.	Navarro - Webberville beds with arenaceous concretions.	Beginning of *E. costata.* *E. Ponderosa*, sub-costate var. Culmination of *E. Ponderosa*, Rœm.	Main or eastern portion of the Black Waxy Prairie area of Texas, seen in Colorado section from Montopolis bridge to Webberville, especially at Blue Bluffs of Colorado. Walnut Creek, Travis Co.
3. "White rock" or Austin-Dallas Chalk Division.		*Hemiaster texanus.* *Inoceramus.*	In eastern portion of Austin, underlying all the chalky portion of city. Also at Waco, San Antonio, Dallas, McKinney and Sherman.
2. Eagle Ford Clays (Shales).	Upper Calcareous Clays.	*O. Bellaplicata*, Shum.	Minor Black Prairie or Mountain Creek Prairie, lying between white rock scarp and Lower Cross Timbers.
	Lower blue clays, with giant nodules.	*Hoplites* (*deshayei?*).	
1. Lower Cross Timber Sands.†			Coincident with extent of Lower Cross Timbers south of Grayson Co.

† Missing in Colorado River Section.

A.

The Lower or Comanche Series (Colorado River Section.)

DIVISIONS.	BEDS.	*Sub-Divisions.*	HORIZONS.	TYPICAL OCCURRENCE.
3. Upper or Washita Division.	Shoal Creek Limestone (at Austin). (Impure.)		In North Texas replaced by Denison or O. *Quadriplicata* beds.	Shoal Creek, Austin. S. bank of Colorado, at fish ponds.
	Exogyra arietina clays.		Final *G. pitcheri*, var. *navia E. arietina.*	Shoal Creek at Twenty-fourth Street. Bluff near Barton Springs.
	Washita or Fort Worth Limestone (chalky).		*Terebratula Wacoensis.* 3d Gryphæa beds. *G. Washitaensis*, with *O. Carinata*, *O. Sinuata*, *Macraster elegans.*	Fort Worth, Texas; railroad cut, W. Austin, Salado, etc.
	Upper Caprotina Limestone.		Final *Caprotina* horizon.	S. base of Bonnel; McDonald's brickyard, Austin.
	Limestone Flags.			
2. Middle or Fredericksburg Division.	Caprina chalky Limestone with flints. (Persistent.)		*Schloenbachia acuto-carinatus.* (*A. peruvianus*, de Buch, Marcou.) *Rudistes*, *Monopleura*, *Caprotina*, etc.	Summit of Jollyville and Jehosaphat Plateaus, and bluffs of Deep Eddy, Austin.
	Comanche Peak chalk beds. (Persistent.)		Comanche Peak Fauna, *Ammonites pedernalis*, *Toxaster texanus.* *G. pitcheri* beds, with *E. texana.* Culmination bed of *E. texana.*	Comanche Peak, etc. Summit of Mount Barker, and many other localities. Bench of Mount Barker.
	Lower or alternately arenaceous, magnesian calcareous division.	Upper beds of thin oolitic strata.	*E. texana.* *Tylostoma pedernalis.* (Goniolina ? Beds.)	Summit of Mount Bonnel above celestite beds. Bases of Mounts Barker and Bonnel, north of fault.
		Middle beds, with thick magnesian strata.	Celestite beds. *Nerinea Austinensis.* *Tinoporous* chalk. (Goniolina ? Beds.)	Base of Bonnel ridge, near Bull Creek.
		Basal arenaceous beds, with thin strata.	*Nerinea acus.* 1st *Caprotina* horizon.	Travis Peak P. O.
1. Lower or Trinity Division.	Upper or Packsand Beds. (Locally variable.) Basal or Contact Beds. (Locally variable.)			Sycamore Creek, Burnet County; Travis Peak P. O., Travis County.
Pre-Cretaceous.				

DISTURBANCES OF THE STRATA.

It has been said in the previous pages that the rock sheets composing the two Cretaceous series were comparatively uniform in their relative inclination towards the sea, and that successively lower and lower (older) strata succeed each other to the westward. In places the uniformity and continuity of structure is somewhat disturbed by jointing, faulting, and denudation of the strata. In the vicinity of Austin these joints and faults are especially conspicuous, no less than five of them being readily discerned between the eastern limit of the city and the top of Mount Bonnel. Their general direction is north, 20 degrees east, but occasionally there are complemental directions to these. The downthrow of these faults is usually to the east, but in two exceptional cases it is reversed. The amount of this downthrow in most of these faults is less than 100 feet, but that of the main one, which runs from Mr. Huck's mansion parallel with the river, is over 500 feet, probably 750, so that the rocks underlying the region east of the Bonnell ridge have fallen down from their former higher position. Accompanying the downthrow of this fault are a large number of abnormal folds, usually dipping in every direction, forming numerous low anticlines and synclines when exposed. The rocks in the vicinity of these folds are usually metamorphosed into marble, and their exact origin and relation to the proximate faults and volcanic phenomena are seen seven miles southeast of the city, where the uniformity of structure is again broken by an extrusion of basaltic rock at Pilot Knob.

The main, or Mount Bonnell, fault is one of the most conspicuous features of the region, belonging as it does to a line of fracture extending from the San Gabriel to the Rio Grande, and which in the southwest bears the appropriate name of the Balcones. This fracture in the earth's crust is marked by an escarpment of from one hundred to two hundred and fifty feet in height, the eastward face of which is usually composed of the basal, or alternating, beds, while the summit, which is the plateau of the main Grand Prairie, is composed of the hard Caprina limestone. The downthrow, or region to the east, as seen in the country between Austin and Oatmanville, or between Austin and Mount Bonnell, is more or less crumpled and broken by minor accompanying fractures, accompanied by much metamorphism.

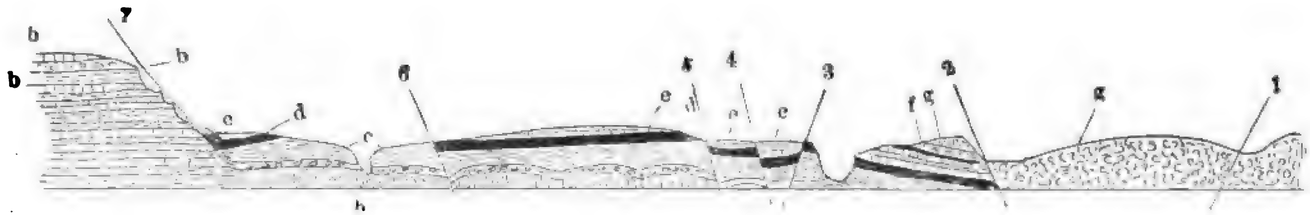

FIG. 5.—Cross section from Waller Creek, East Austin, through Mount Bonnell to the Bull Creek plateau, showing faults.

g. Austin chalk.
f. Sixth Ward (Eagle Ford) clays.
e. Shoal Creek limestone.
d. Exogyra Arietina clays.
c. Washita limestones.
b. Caprina limestone and flint beds.
a. Alternating, or magnesian, beds.

1. Waller Creek fault in chalk.
2. Sixth Ward fault.
3. Shoal Creek and Twenty-fourth Street fault.
4. Slaughter house and Bonnell road fault.
5. Sieder's Spring fault.
6. Half mile west of railroad.
7. Mormon Spring, or Mount Bonnell, fault.

The aggregate thickness of the Comanche and Black Prairie series approximates nearly four thousand feet of strata, and they play a most important part in the geologic history of the United States. It is not our purpose at the present time, however. to enter into the philosophic aspects of these strata, leaving for the future the interpretation of the effect these two profound subsidences have had in the building up of our continent and its history, and the interpretation of the ancient and beautiful forms of life imbedded in the strata. It is sufficient to say that the day has come when it is not essential to discuss together the Comanche series and the Upper Cretaceous series, so different are they in geologic age, although they possess the following similarities: (1) Each is composed of sediments laid down upon a slowly subsiding and rising sea bottom, thus recording all the different ocean depths, from littoral or shore condition to deep sea. (2) The general strike and dip of their rocks are in the same direction. (3) Each is characterized more or less throughout by an excess of lime—usually in the form of chalky calcium carbonate, pure, or mixed in every imaginable proportion with sand or clay.

Notwithstanding these resemblances, the separate identity of the two series is shown by (1) the absolute stratigraphic break between them, as can be seen in numerous contacts in the city of Austin and elsewhere; (2) the radical change in character of sediments, as seen along the partings of the Lower Cross Timbers and the Comanche series; (3) the absolute change of life in the two formations, not a single species, as far as known, passing from the Lower series into the Upper, thus indicating a lapse of time between them sufficiently long for an almost complete change of specific characters in the ocean's inhabitants. They are as distinct from each other in origin and occurrence as they are from the rocks of the overlying Tertiary and Quaternary systems, and hence it is necessary to describe them separately.

These ancient ocean bottoms have undergone wonderful transitions. Originally the mud and ooze beneath hundreds of fathoms of ocean water, they now form an elevated, healthy land. The noiseless life of their depths is replaced by a busy population of intelligence, who build, plow, and quarry, and in a thousand ways utilize the rocks of the former sea bottom. Vegetation finds in the decay of these reclaimed ocean beds a matrix for its rootlets, which are nourished and sustained by the rich remains of the ancient life imbedded in them. Mankind, with the ever-growing art of agriculture, improves upon this natural vegetation a hundred fold, and civilization grows where archaic silence once reigned supreme. If the transition from the past to the present has been so great under our pioneer methods, what does the future of science, with its experiments and constantly increasing knowledge, portend?

ONION CREEK—TRAVIS COUNTY.
CONTACT OF AUSTIN CHALK AND VOLCANIC ASH.

GENERAL ECONOMIC FEATURES OF THE CRETACEOUS SYSTEM.

The foregoing observations and conclusions are only introductory to the great work which yet remains to be done in order to make the natural conditions of the Cretaceous formations appreciated from a utilitarian standpoint. To bring them properly before the attention of the people, it may be proper here to give a brief statement of the economic features now under investigation.

Soil Survey.—As the region under observation is essentially an agricultural one, the first and most important economic problem is a study and definition of the great variety of agricultural soils within its bounds, in order to increase their usefulness and provide for their preservation. With a few unimportant exceptions of transported or alluvial soils existing in the river bottoms of the region, these soils are mostly residual—i. e., the direct product of the weathering of the underlying rock sheets—and consequently they present a great diversity of qualities, varying with the underlying rock sheets. Although, with a few minor exceptions, the soils are mostly calcareous, there are many species of them, and each possesses some peculiar virtue or deficiency for the growth of plant life. A geological map of the region, when published, would accurately show the distribution of each of these diverse soils, with descriptions of their qualities, thus placing our land values upon a more stable and equitable basis, and enabling the farmer to use his soil for plant growth in an accurate and definite manner, and to improve it, if necessary, by an intelligent application of mechanical methods or fertilizers. This classification of soils has advanced so far that in another year it is hoped a final report may be made upon them for the northern area.

The methods pursued in these soil investigations are as follows: The exact geologic origin of the soil is ascertained, by minute observations of the processes of disintegration of the rock or clay from which it is derived, with especial reference to its mechanical condition, chemical composition, and native plant growth.

The average depth and hygroscopic conditions and permeability are also observed. The individuality of a soil having thus been determined, the tracing of its extent is conducted coincident with the tracing of the rock sheet from which it is derived. Due allowance is made for topographic variations; the soils of the Grand Prairie region, for instance, being of little depth except upon the high divides and mesas or in the valleys, the valley slopes being mostly sterile.

So important is this soil survey deemed that it is perhaps no exaggeration to say that, with proper co-operation of our experimental stations, it will

ultimately result in an intelligence of the agricultural possibilities of the region that will greatly enhance our prosperity.

Many specimens of the representative soils have been collected and placed in the hands of the chemical analyist for further study. The chemical analysis of no soil is undertaken, however, until every mechanical and other method is resorted to in its definition, and no soil is analyzed whose geologic origin and distribution is not first ascertained; because, as has been abundantly shown, much waste by the promiscuous analysis of soils should not be encouraged.

MINERAL FERTILIZERS.—The region is especially rich in these, and attention is being devoted to their thorough description. While fertilizers at present may not be needed upon any soil within the area itself, nor used to any great extent in the State, they will ultimately be of great service upon non-calcareous soils, especially in the East Texas region, at an early day, and ultimately become a valuable export material. Among the valuable mineral fertilizers abundant in the region, which in other parts of the world are highly esteemed for their great value in agriculture, and are the source of large revenues both for domestic use and exportation, are greensand or glauconite marls, shell marls, chalk marls, and gypsum marls. In addition to these it is also highly probable that valuable phosphatic marls may be discovered, as the exceedingly fossiliferous beds of certain localities are very propitious for their occurrence, which can only be determined after careful investigation.

Especial attention is also paid in the final report to the question of marling and mixing of soils, after the soil distribution and classification has been completed.

The field of agricultural geology in this region, when properly investigated, bids fair to reveal new economic possibilities at present hardly dreamed of, and to render its already fertile soils more available by a proper understanding of their uses and defects, which, together with the abundance of water to be supplied by artesian wells in places to be determined by the survey, will increase many fold the country's capacity for productivity and population.

WATER CONDITIONS.—A question of great importance to the Cretaceous region is that of water conditions, and much attention has been given it. The ascertainment, utilization, and improvement of these, instead of being a matter entirely of rainfall, as is usually supposed, is more a question of structural conditions of the rocks which underlie the region. It may strike the reader as a bold proposition to state that a fall of fifteen inches of rain in proper season per annum upon one field may be of more value than a hundred inches upon an adjacent one, if they be of two different formations. One

formation may imbibe nearly all of the rain which falls upon it; another may imbibe less than one per cent of it.

Another stratum may become saturated and slowly yield its moisture to agriculture, as in the case of the Ponderosa clay marls underlying the main black waxy area; while another, like the upper Cross Timber sands, may give up its moisture so rapidly, owing to its porosity, that it is poorly adapted to stand drouth and heat. Again, as has been said, one rock sheet may drink in much of the rainfall and convey it through the pores to a lower region, where by boring from above they may be tapped and come forth as abundant artesian waters for a streamless and springless region. By the study of the dip and extent of such a sheet, we have been enabled to accurately predict the extent and importance of an artesian area, the value of which, when fully appreciated, to the people in the region in which it lies will be greater in dollars than the cost of this survey; for by the simple knowledge of this fact artesian water can be supplied to an area of 30,000 square miles of one of the most fertile districts in America.

LAND CLASSIFICATION.—An important part of the work is the classification of the lands of the region according to their agricultural, grazing, mineral, quarrying, watered, arid, timbered, prairie, or other conditions. The work of the past year has already accomplished much in this direction, inasmuch as the general characteristics of areas have been determined, a necessary step for the more specific classification which must ultimately follow.

STRUCTURAL MATERIAL.—There is a great variety and abundance of building materials of the Cretaceous formations, but the task of studying them is so large that the work can hardly be considered begun. Building stones of many qualities, paving stone, road material, cement stone, Portland cement material, hydraulic cement material, fire-brick and tile clays, gypsum for plaster of paris, sands for diverse uses, flint for glass making and sandpaper, all appear in more or less abundant quantities in the Cretaceous rocks, and need careful investigation and description.

In their development lies a twofold source of wealth, in that they will not only attract an intelligent capital to their development, but place in the hands of our own people cheaper and more convenient building material. Among the building stones there are are many varieties which deserve especial attention as worthy of export; while with chalks, clays, and every variety of magnesian limestones, the region will no doubt become the centre of a great American cement industry, like that of England, and such as can not exist elsewhere in the United States, owing to the fact that it is in this region only that the chalky formations upon which the English cement conditions are dependent occur. One rock sheet (the Caprina limestone) already affords

the material for a commercial lime of unexcelled purity, which is now shipped as far east as New Orleans, and west to San Francisco.

MINERALOGICAL FEATURES.—The Cretaceous formations east of the Pecos are not a profitable field for the search for metallic minerals, owing to their slightly disturbed condition. There are many beautiful and rare forms of the non-metallic minerals of the lime group, but none of great value.

Gold has been found in small and unprofitable quantities in the chalky regions of Williamson County, as recorded by Schaeffer, but there is hardly a possibility that it will ever prove of commercial value. Its mode of occurrence and distribution, however, will be exhaustively examined into, so as to settle the question beyond cavil. Occasional nodular lumps of limonite iron ore, often of deceptive size, are found in the Caprina limestone, but in no case have I seen a locality where a cart load could possibly be gathered. Calcite, aragonite, celestite, gypsum, anhydrite, occur in great abundance in places, as well as flint, chalcedony, agate, opal, etc., all of which are upon the list for further study. A large amount of information concerning the general occurrence and distribution of these has been collected, preliminary to their final study.

PLANT AND ANIMAL LIFE OF THE CRETACEOUS REGION.—Any one who attempts to observe the character and distribution of life in the Cretaceous region of Texas will soon be impressed with the fact that it possesses floral and faunal conditions peculiarly its own, which no existing classifications or text books sufficiently explain; and he will find that these conditions also vary with the subdivisions, and that there is a most intimate relation between the substructure and the life which inhabits it, especially exhibited in the plants. Thus it is that the Exogyra Ponderosa marls are singularly void of forest growth; that the evergreen oaks are fond of the White Rock and Shoal Creek limestone; that the juniper loves the Caprina limestone; while the unique and beautiful Sophora (Mount Bonnell laurel) flourishes only in the magnesian beds of the Lower Fredericksburg division. The post oaks and black jacks tenaciously inhabit the sandy formations, such as the Upper and Lower Cross Timbers, and the Quaternary debris of the river terraces. This natural plant growth will prove the surest guide to the most appropriate agriculture to which the region is adapted. Lists of many of the plants have been kept, which, together with the observations of previous observers, and more careful investigations to be undertaken during the coming season, will prove of great value.

It is popularly supposed that observations upon the animal life in general are of less economic importance, and are of interest and value only for educational purposes. The insects, mammals, and birds may be destructive or protective to vegetation. They are therefore of great economic interest.

In concluding this paper, the writer can not omit the opportunity to urge

upon the people the necessity of recognizing the chalky formations of Texas as a distinct geographic region of the State and the United States. This individuality must be recognized, and the economic development of the region based thereon, instead of the conditions of the entirely different non-chalky regions of the United States from which most of our settlers have come. The agricultural experiences of Massachusetts, Mississippi, or even East Texas, will not apply to these soils, but we must rather go to the chalky regions of France and England, where analogous formations occur, to learn for what they are best adapted. Experiment stations should be located upon these soils and their utility fully determined.

The Black Prairie region, which is already one of the most prosperous in our State, will greatly increase in value with coming years, as its agricultural capacities are more fully appreciated and improved upon. The already rich land now given up to the culture of coarser plantation crops, such as corn and cotton, will ultimately be devoted to more refined agriculture, as the soils are better understood, and a local demand is created for the products. With this rural development will continue the growth of its cities, which has been wonderful even in the past decade. It only remains to ascertain in a scientific manner the exact capacity and adaptability of these soils, and to improve facilities for transportation and communication.

THE

SOUTHERN BORDER

OF THE

CENTRAL COAL FIELD.

BY

W. F. CUMMINS.

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The exploration upon which this report is based extended over parts of Lampasas, San Saba, Coleman, McCulloch, Concho, and Tom Green counties. The object of the trip was to secure such general information regarding the section as would indicate the special lines of work that could be most advantageously pursued in the detailed survey of this region.

DESCRIPTIVE GEOLOGY.

During the present expedition strata belonging to the Silurian, Carboniferous, Cretaceous, and Recent systems have been observed, some of which will be more fully mentioned under separate headings, but their boundaries must be left for more detailed work.

The different formations have been identified either by their fossils or by their relative positions in regard to other known strata. There is great uniformity of structure in the individual strata of the several formations over the entire field; so much so that one becoming familiar with the characteristics of a stratum in one place need have little trouble in recognizing it elsewhere when found.

The strata of the Paleozoic Group as observed along the route have a general and uniform dip to the north and northwest, with little or no disturbance, except in one or two instances which are noted. The Mesozoic strata, on the contrary, have a general inclination to the southeast.

Few evidences of faults or folds of the strata in any of the formations were seen, except where they are in contact with the eruptive rocks. The alternations of limestone, sandstone, and shales in the various formations show that the periods of their deposition were attended with alternating conditions of subsidence and elevation.

CRETACEOUS SYSTEM.

The rocks of the Cretaceous system are found in contact with strata of both the Carboniferous and Silurian, showing that the Silurian and Carboniferous

strata had been tilted to the northwest before the Cretaceous period; and as the Cretaceous is found on or in contact with every stratum of the Carboniferous and Permian, from the highest to the lowest, there is little doubt that the Cretaceous strata at one time extended continuously from the foot of the Staked Plains to the Cretaceous beds on the east, and that the present exposure of the underlying Paleozoic group is due to their subsequent erosion.

The Cretaceous formation in this part of the State belongs entirely to the Lower or Comanche series. The beds have a thickness of about 200 feet wherever seen, except on the upper South Concho River, where the thickness increases to about 400 feet.

A section made at Santa Anna Mountain will give a general idea of the Cretaceous formation as observed in this part of the State.

No.	Strata.	Feet.	In.
1.	Compact limestone	8	
2.	Limestone with fossils, silicified	2	
3.	Limestone, compact	4	
4.	Limestone, soft	66	
5.	Shell concretion		6
6.	Sandy clay, white	20	
7.	Reddish clay	2	
8.	Pack sand	50	
9.	White loose sand	20	
10.	Red clay	2	
11.	Sandstone	13	
12.	Reddish clay, with bands of white sand	20	
		205	6

The following section was made at Cow Gap, a pass in the Brady Mountains, in McCulloch County:

No.	Strata.	Feet.
1.	Limestone, hard	20
2.	Limestone	80
3.	Rotten limestone, with beds of sandy clay	100
4.	Pack sand	10
		210

No. 1 in the above section had the same fossils as No. 2 in the section made at Santa Anna Mountain.

The principal fossils found and identified in this formation were *Gryphæa pitcheri* and *Exogyra texana*. These Cretaceous strata rest directly and unconformably upon the clays and sandstones of the Carboniferous.

CARBONIFEROUS SYSTEM.

The Carboniferous system extends over the largest part of the country examined during this trip, and to it the most of the time was devoted.

No attempt is here made to separate the Subcarboniferous from the Carboniferous. In fact I am not certain that the Subcarboniferous formation occurs. The strata of the entire series, so far as I observed them, are conformable and the fossils found in the lower part of the formation were not characteristic of the Subcarboniferous, but are those which are for the most part embraced in the fauna of the coal measures. I am certain, however, that there is a section at least 400 feet thick, lower than the strata of the coal measures which are found in the northern part of the State.

The Permian formation was clearly distinguished overlying the coal measures on the west.

The general dip of the strata of this system is to the northwest at about 30 feet to the mile, except near Lampasas, where the dip is to the northeast, which may be accounted for either by the existence of an anticlinal in the western part of Lampasas County, or possibly by faulting.

The strata of the Carboniferous are composed of limestones, sandstones, clay beds, and shales, with three or more beds of coal. On top of the measures in many places is a bed of conglomerate similar to that found overlying the coal measures in the northern part of the State.

The measures are about 1600 feet thick, so far as examined, although their upper part was not reached. In many places the strata are so deeply covered up with drift that it was impossible to get a continuous section, and the thickness is therefore estimated by the known dip of the strata, where a section could not be made by actual measurement. Many sections were made at different localities, with the hope of being able to secure a continuous section, but there are gaps that can only be filled by estimates of thickness, based on dip and the distance occupied by the wanting section. Enough, however, has been done to give a very correct idea of this formation, which can be worked out more in detail in the future.

The Carboniferous limestone was first observed at the mineral springs of Lampasas, where the water issues from a fissure in a blue limestone belonging to this formation. The limestone dips east at an angle of one and one-half degrees.* On the top of the limestone is a yellowish marl which seems to be more disturbed or flexed than the underlying material. The limestone contains such distinctive fossils as *Spirifer cameratus*, *Productus costatus*, *P.*

*The dips here given are from careful instrumental measurements—frequently of lines of considerable length—by Mr. C. C. McCulloch, Jr.

cora, and a great many stems of *Encrinites*. Below the spring is a bed of recent conglomerate made up of the water-worn pebbles from the surrounding hills. Three miles west on the Llano road, at the forks of the creek, the limestone extends across the creek from the south side. The massive limestone (which may be Silurian) dips here to the northeast, and is about twenty feet thick. Above it is the hard blue limestone which was seen at the spring. Above that is ten feet of the yellow shale, and above that ten feet of shaly limestone. The fossils seen are evidently those of the Carboniferous, but they have been badly pressed and are out of shape.

Six miles west of Lampasas, in the bed of Donaldson's Creek, is a black, thin-bedded limestone, which dips 1¼ degrees north 20 degrees east, with a line of jointing north 89 degrees east. Above this limestone is a hill sixty feet high, the only stratum exposed being a fine grained blue limestone with chert nodules.

Three-fourths of a mile east of this last named place is Indian Bluff. This is a perpendicular bluff, seventy feet high, composed of thin layers of limestone, hard, black and shaly. This limestone overlies the rocks of the last locality.

At the top of this hill, in the fossiliferous limestone and in the chert nodules, I obtained the following Carboniferous fossils: *Spirifer cameratus*, *Pleurotomaria turbiniformis*, *Bellerophon crassus*, *Spiriferina kentuckensis*, *Productus nebrascensis*, *Platyceras nebrascenis*, *Euomphalus rugosus*, *Myalina subquadrata*, *Synocladia biserialis*, *Bellerophon carbonarius*, *Machrocheilus fusiformis*.

The material in which these fossils occur is so hard that it is very difficult to get good specimens of the fossils, and many of them could not be separated from the matrix. In places the fossils are so badly distorted by pressure that they could not be recognized. Especially is this the case with those found in the black shale.

Just west of Nix, the overlying Carboniferous sandstone is exposed for one mile, when the Carboniferous limestone again appears. The dip of the strata here is to the north, and at about 2 degrees. In this limestone were found *Productus semireticulatus*, *Productus punctatus*, *Nucula bellistriata*, *Chonetes*, spines of *Archeocidaris*. These fossils are mostly in the chert or flint nodules found in the limestone. The limestone on top here very closely resembles the cherty limestone seen at Indian Bluff.

Near Mr. McRae's, fifteen miles west of Lampasas, are several caves, none of which were explored. At another place, near by, the massive limestone has been very badly fractured, and the water having carried off all the overlying material, some of the fractures are open to twenty feet in depth. This stone is that which is called Burnet marble, and is near the boundary be-

tween the Carboniferous and Silurian formations, probably belonging to the latter.

Along Lynch Creek there is a bed of very hard black thin-bedded limestone, that can be obtained in very large slabs of uniform thickness. These slabs would make very fine flagstones. The sandstones are on the north side of the creek, and the limestone on the south, all the way from its head to the Colorado River. The creek seems to run on the contact between the limestone and the sandstone the entire distance from the head to its mouth. On the west side of the Colorado, there is a fine exposure of the Carboniferous shale, with thin beds of black limestone below. In the limestone and in the top of the shale are many fossils. The species are quite numerous and very abundant. Just above the limestone, in the black shale, part of the head of a vertebrate was found which resembles *Edestus vorax*.

The following section, made on the south side of the Colorado River, near Bend postoffice, will give the relation of the strata:

	Feet.	In.
1. Conglomerate	7	
2. Brown shale	20	
3. Black shale	22	
4. Limestone, black, hard	4	
5. Bluish shale	3	
6. Limestone	4	
7. Bluish shale	3	5
8. Blue limestone, bed of river	6	

The strata dip 1¾ degrees north 23 degrees west. There are two lines of jointing, one north 77 degrees east, the other north 47 degrees west.

In No. 4 of the above section there are large masses of coral *Chaetetes radians*, that I have seen only in this limestone. This species is not mentioned in Miller's "N. A. Paleontology" as occurring in North America.

At the mill near the mouth of Rough Creek the sandstones lie immediately upon the limestone, the shales having entirely disappeared below the sandstone, showing an overlap. Up the west side of the creek are the massive limestone hills extending for a mile or more, but in the next hollow the sandstone is found on top of the limestone as before. The sandstone is here composed of larger grains of sand than before observed, and has more the appearance of a conglomerate. South of this, Rough Creek cuts through the massive limestone, below which is the thin-bedded black limestone, from which the same fossils were secured as were gotten at other localities.

Two miles southeast of Mrs. Houston's, on Cherokee Creek, there was said to be a stratum of lithographic stone. The stone was found in a cave as represented, but the quality is not good enough to make it of any commercial value. One-half mile southeastward the same stratum of lithographic stone

was observed outcropping on the side of the hill. It was then traced along the outcrop southeastward for three miles or more, and the quality found to be about the same all the way. This is the same stone found in Hill's pasture, a little northeast of the Sulphur Spring on the Colorado, the horizon being readily determined by the similarity of the surrounding rocks.

In the bed of Cherokee Creek there is a dark limestone, with small fragments of coal outcropping in the side of the bluff. The coal is of no commercial value, and there is no probability that it will be better if traced to another locality.

At Simpson Creek, two miles south of the town of San Saba, the same blue limestone that is seen below the black shales at McAnnelly's Bend was found, and also at the spring at the town. In this blue limestone, just east of the spring, is found a stratum containing the same coral as the limestone No. 4 of the section made on the Colorado just west of Bend, and also north of Cherokee Creek. On the north side of the San Saba River, one mile north of the town, there is another exposure of the black shales, which are here 30 feet thick, with identically the same fossils as found at Bend. From a trip up the San Saba River, from San Saba to near the mouth of Brady Creek, careful observation seems to indicate that the river runs most of the way along the strike of these black shales. One mile northeast of Doran's Ranch house, near Brady Creek, there is another outcrop of black shale between the limestones, which is evidently the same stratum as that found between the limestones at Bend. Again, on the south side of the river, and a half mile south of the ranch house, there is a bluff of 60 feet in height, showing strata of blue limestone and shale, very much resembling the strata at Indian Bluff, in Lampasas County; the only difference being that at this place the layers of limestone are somewhat thicker. Underlying this is a bed of massive limestone that in places has been changed to marble. There is also a similar bluff on the north side of the river, half a mile west of the ranch house. The river cuts through these strata, and also through the massive limestone, which continues to be visible to the mouth of Brady Creek. In the massive limestone, about half a mile below the mouth of Brady Creek, there is a fissure crossing the river at an angle of north 30 degrees east, filled with carbonate of iron and iron pyrites. The vein cuts the bluff on the north side of the river, and can be traced by the iron outcroppings for several miles. It was traced very readily across the hill for more than half a mile, and seemed to contain about the same amount of iron all the distance. The vein is from one to two feet wide.

Along the Goldthwaite road, north of San Saba about six miles, there is a hill 60 feet high capped with the Carboniferous sandstone. The bottom of the hill is composed of bluish and yellow clay shales, on the top of which is

the even grained gray sandstone, which is about six feet thick. In the sandstone were found impressions of Carboniferous plants, *Calamites*, etc., but no other fossils were observed. This stone has been used in the town of San Saba and vicinity for building, for which purpose it is a fine material.

Crossing the San Saba River north of Richland Creek, and traveling up the divide between it and the San Saba River, there is found near the mouth of the creek, on the north side, a hill showing the bluish and yellowish clay at bottom with the sandstone four feet thick at the top. At several places along the way the same formation is seen, but always on the north side of the road. On the south side, in the creeks running into the San Saba, the black shales appear. At Richland Springs, on the slope of the hill, are found the thin-bedded limestones with thin seams of black shale, as seen at other places. These black shales are also found on Job's Creek, a few miles south of this locality, where they contain the same fossils as at Bend. Some of the houses in the town of Richland Springs are built of a light stone which is here the equivalent of the upper stratum at Indian Bluff. Carboniferous sandstone is found near this place on the north side of the creek.

One mile above the crossing of the Colorado, north of Milburn, McCulloch County, and on the north side of the river, is an exposure of strata 80 feet thick, composed of blue shale, with thin beds of sandstone, having a massive sandstone on top. In the shales, and in a thin stratum of shell conglomerate, were found the following fossils: *Productus nebrascencis*, *Athyris subtilita*, *Aviculopecten occidentalis*, *Myalina subquadrata*.

From the Colorado River to the head of a prong of Clear Creek, on the Brady and Brownwood road, occasional exposures of the Carboniferous sandstones were seen. On the head of Clear Creek the massive limestone of the Carboniferous was again found, but no fossils were to be obtained.

In this limestone, near Trickham, are some very large *Campophylla* associated with *Fusulina cylindrica*. The shaly limestone is 20 feet thick, and is underlaid by a blue clay, as is shown by well borings.

One mile north of the town is a hill some 60 feet high. The bottom is composed of shale, with nodules of clay ironstone, and the top is capped with a massive sandstone 8 feet thick. The sandstone here is coarser in structure than is usually seen in the Carboniferous.

On a hill still further northwest is a compact limestone above 10 feet of the shale, which here overlies this sandstone. The dip of the strata is to the northwest.

In Dunson and Kingsbury's pasture, 6 miles west of Trickham, there is an exposure of the same strata, with sandstone 4 feet thick on top; yellow clay 10 feet thick, and bluish clay 8 feet thick at the bottom. In the yellow clay there are a great many nodules of clay ironstone, and in the nodules

quite a number of the characteristic fossils of the Carboniferous period: *Spirifer cameratus*, *Productus nebrascensis*, *Myalina perattenuata*, *Orthoceras*, *Fusulina cylindrica*, *Hemipronites crassus*, *Discina convexa*, *Chaetetes milleporaceus*.

Over the entire surface of the valley here there is found a bed of conglomerate, the gravel of which comes from the surrounding strata.

At the head of Dry Creek we came to an exposure of limestone capped by a shale and a heavy-bedded sandstone. The same limestone as seen at the crossing on Dry Creek appears also in the bed of Camp Creek, and two miles further on, after going up a slope from Camp Creek, there is a hill 80 feet high made up of clay beds, limestones, and sandstones. In a bed of clay about half the height of the hill are a great number of *Campophyllum torquium*.

Mr. J. W. Gibson has put down several prospecting holes in this vicinity south of the hills, and in the valley of Little Bull Creek. The only shaft open at present is about one mile east of the creek, and is west of the principal outcrop. This shaft is 48 feet deep. The last 3 feet was through a stratum of coal; the coal is reported as 24 inches thick at the bottom, then 2 inches of slate, and then 10 inches of coal. In a bank of the creek 400 feet northeast of the shaft the coal crops out about 8 feet above the bed of the creek. Here the upper seam of coal is 20 inches thick and the lower seam 8 inches thick, with a thin seam of slate between. One-fourth of a mile northeast, and on the east side of the creek, the coal again outcrops, showing about the same conditions. The dip of the strata at this place is about 30 feet to the mile to the northwest.

There are several outcrops in the vicinity of the coal on the east side of the creek. In places the seam is not more than 4 inches thick. The coal has over it, clay 6 feet, shaly limestone 10 feet, and a rough, thick sandstone. Below the coal is a bed of fireclay 2 feet thick. In the bed of the creek, just east of the shaft and below the fireclay, is a bed of sandstone.

The Williamson shaft is located one mile northwest of the town of Waldrip. A few years since a company, at a heavy expense, put down this shaft, 8x8 feet, to the depth of 160 feet, and timbered it from top to bottom.

It is reported that a bed of coal only twelve inches thick was found, that it dipped to the southwest, and was eighteen inches thick at the south side. The shaft has been abandoned and is nearly full of water. From the material taken out I think it to be the same as that found on the east side of the river.

The Chaffin mine is two miles southeast of this shaft. The coal has been mined here to some extent at different times. The seam is twenty inches thick and is immediately below a shaly limestone and very much resembles the coal found west of Trickham, in Dunson and Kingsbury's pasture, and I

take it to be a lower seam than the one in the Gibson shaft on the north side of the Colorado. The dip is to the northwest. The coal was mined from the surface by following the seam from the outcrop to the branch.

The Finks mine is one-half mile west of the town of Waldrip. The shaft has been put down to the depth of eighty-four feet. In the bottom is a seam of coal twelve inches thick, then a thin parting, then four inches of coal, then a thin parting, and finally another bed of coal twelve inches thick. A tunnel has been driven from the bottom in an easterly direction for forty feet, and the coal taken out for some distance on either side. Work on the mine has been stopped for the present.

The following section was made at this mine, beginning at the top.

	Feet.	Ins
1. Purple clay		8
2. Yellow clay		8
3. Massive sandstone		4
4. Coal		4
5. Yellowish clay	20	
6. Clay	17	
7. Limestone	18	
8. Yellow clay		28
9. Coal		28
10. Fire clay		12

A shaft fifty-five feet deep was put down near the river and struck the same seam of coal.

A section of a hill in Mahoney's pasture, two and a half miles southwest of Santa Anna, gave the same strata as those observed west of the mountain—sandstone on top, with clays and limestone below.

Below the red clay is a bed of limestone three feet thick, and below that is a bed of reddish clay twenty feet thick. Near Mahoney's house there is a hill showing the same bed of sandstone that is on the top of the hill west of Santa Anna at about half the height of the hill. Above the sandstone there are twenty feet of yellow and purple clays, and a hard limestone eighteen inches thick rests on that.

In this limestone are again found deposits of a soft material like the diatomaceous earth.

In the bed of the creek, half a mile southeast of Mahoney's house, there is a bed of bituminous shale 18 inches thick, with a bed of blue limestone below it three feet thick. Still further down the creek, to the southeast, there is in a bluff the same bed of limestone, with blue shale below it, which is 20 feet thick. The bottom of the slate was not seen.

In the valley of Home Creek, in many places, there is a conglomerate composed of the rocks from the surrounding strata.

In one place, above the highest sandstone, is a conglomerate that very much resembles the "bean ore" found in the Permian in Archer County.

In Cow Gap, a pass through the Brady mountains, the following section was obtained:

	Feet.
1. Hard limestone	20
2. Limestone	80
3. Rotten limestone with beds of clay	100
4. Pack sand (Cretaceous)	10
5. Massive limestone (*Fusulina*)	3
6. Limestone	6
7. Shaly limestone	10
8. Reddish clay	10

No. 1 of this section has the same fossils as No. 2 of the Santa Anna Mountain. At the base of the Cretaceous, but apparently not a part of it, is a conglomerate which very much resembles the conglomerate and sandstone at the head of Lynch's Creek, in Lampasas County. Cow Gap is almost directly south of Santa Anna Mountain, and the Brady range of mountains runs east and west. The dip of the Carboniferous is to the northwest and that of the Cretaceous to the southeast.

Nine miles west, at the head of Live Oak Creek, was found an outcrop of the Carboniferous limestone containing *Fusulina cylindrica*, *Meekella striato-costata*, and a *Terebratula*. The limestone is quite shaly.

South of Brady along the Menard road, three miles or more, there is a bed of conglomerate composed of small siliceous pebbles bound together by a siliceous matrix.

This conglomerate is so compact as to take a fine polish, and the pebbles being of very bright color it makes very handsome ornaments.

Southeast, at the head of Rocky Creek, there is a pass between the hills. The hills are about 30 feet high above the pass, and are Cretaceous, containing such fossils as *Gryphæa pitcheri* and *Exogyra texana*. Half a mile further south, on Rocky Creek, the rocks of the Silurian appear, but no fossils were found.

On the north side of the river, opposite Camp San Saba, there is a bluff showing a section of thin-bedded, fine-grained, purple sandstone that has been extensively quarried to make chimneys. It is called in this locality soapstone, but it has none of the qualities of that material. There were no fossils found. Over this is a heavy-bedded, even-grained, very hard sandstone 8 feet thick. Half a mile away to the south is the upper limestone of the Potsdam epoch—the glauconitic.

Down Brady Creek, 3 miles toward the east, were found the black shales above the blue limestone, as at McAnelly's Bend. In the limestone there

appeared the same coral *Chaetetes radians* as at Bend and elsewhere. The massive limestones of the Carboniferous rocks are the only rocks exposed near the creek. On top of the hill west of Post Oak Creek there is a bed of sandstone four feet thick. The court house and other buildings at Brady are constructed of this material.

In many places along Brady Creek is a coarse conglomerate composed of pebbles from the surrounding hills. Two miles above Melvin's Ranch house a heavy bed of this conglomerate overlies the Carboniferous limestone.

The country westward up Brady Creek is a level plateau, with Cretaceous hills on both sides, and the Carboniferous in the valley of the creek. Three miles east of the town of Eden, in the bed of the creek, there is a rough limestone containing *Productus semireticulatus*, *Euomphalus*, *Pinna*, *Nautilus*, and stems of *Encrinites*.

The higher hills from here to Kickapoo Creek are Cretaceous. At the base of the hills the Carboniferous strata appear. In a bluff just below the crossing on Kickapoo Creek there is an exposure of 20 feet of Carboniferous beds overlaid by the Cretaceous. The Carboniferous has yellow clay at the bottom, then 2 feet of sandstone, then 18 feet of sandstone and shale, with *Productus semireticulatus;* conglomerate on top.

After leaving the creek the Lipan Flat is reached, which continues to near San Angelo, with scarcely a break and no exposure of the formation. The Cretaceous hills are seen far to the southward, and later they are seen directly to the west and northwest.

San Angelo is situated on the west or north side of the North Fork of the Concho River. The river near the town cuts through the conglomerate, and in other places the conglomerate extends entirely across the stream. Below the conglomerate is a white sandstone 18 inches thick; below the sandstone is a bed of green and red clay.

In the marl is a thin seam of carbonate of iron. Southwest of the town, at a distance of eight miles, red clay was found which very much resembles the red beds of the Permian.

Above the red clay is a whitish sandstone with bands of iron ore, but the iron is not in sufficient quantities to be of any commercial value. Still further to the westward appear the high hills of the Cretaceous. These hills are separate peaks formed by erosion. On top is the thick compact limestone, below which is the Trinity sand, and below that the reddish clay which is always found at the foot of the Cretaceous in this part of the country. The peaks are one hundred and fifty feet high above the Permian clays.

Further south, in the valley of the main Concho, a bed of sandstone was observed that is evidently Permian, resting upon the red clay; and at the old town of Ben Ficklin, on the east side of the Main Concho, was found a

rock quarry of argillaceous sandstone in several layers. In the stone were found Permian fossils, which show the blendings of the old and new forms of life. In the stone were found species of *Productus*, *Ammonites*, *Aviculopecten*, *Orthoceras*, *Nautilus*, *Myalina*, and several other forms that were not identified. The fossils are very similar to those in the Permian in the northeastern part of Baylor County.

Among the number of specimens is what appears to be a new *Aviculopecten*, that I have previously called *A. costatus*.

Below the stone is a bed of green clay three feet thick, and below that a bed of dark red clay. Bottom not seen.

CONGLOMERATE.

There are two kinds of conglomerate found in this part of the State; one of them composed of small much water-worn siliceous pebbles of various colors, bound together sometimes by an iron matrix and sometimes by a siliceous matrix. This conglomerate is generally very hard, and is more often found as bowlders, yet at places it covers many square acres and seems to be in place. It has been thought that these bowlders were left in their present locality by glaciers, but I am sure they are only the remains of a more extensive deposit that was destroyed at the period of erosion. This conglomerate does not occur as a regular stratum in the series, but is found overlying nearly every stratum in the Carboniferous. It seems to be the same conglomerate that is found overlying the Carboniferous formation in the northern part of the State, of which mention is made in my report published in the First Report of Progress of the Survey last winter. It is not so universally distributed in this part of the State as it is further north; at least it seems to have been more nearly destroyed.

This conglomerate in some localities is very compact, and the bowlders are worn smooth by the driving of sand against them by the wind. The materials of these bowlders are usually bound together by a siliceous cement so compactly that they are as solid as a single mass of quartz, and receive an excellent polish and are very beautiful.

Associated with this conglomerate are the only specimens of petrified wood I have seen, and yet they are not associated in such a way as to show that they were deposited at the same time.

There is another conglomerate found along all the rivers and creeks, made up of fragments of stones from the surrounding strata. This conglomerate was deposited at the same time of the erosion, some of it evidently in the early part of that epoch, and some of it at the very last. I conclude that such is the case from the different heights at which it occurred. At the Colorado River, on the hills west of McAnnelly's Bend, a bed of this conglomerate 7 feet

thick is 140 feet above the bed of the river, while higher up the river, and especially along the valley of the Concho, this same conglomerate is found in the beds of the rivers in the lower valleys.

It has no fossils in it, except the water-worn fossils of the surrounding formations. It is usually bound together with calcareous material. The size of the pebbles, and the fact that they are of the same material as the surrounding rocks, show that they have not been carried very far. These deposits are from a few inches to 40 feet in thickness. They are sometimes two and three miles wide.

This conglomerate is found overlying all the formations when they form the strata of the river valleys. I have never seen it on top of a high Cretaceous hill, either on the east or west of the eroded district; but it does occur on top of the high Carboniferous hills on the eastern side of this great valley of erosion.

PETRIFIED WOOD.

Petrified wood was seen at but two places, and at both of these localities it was so situated as to lead me to believe that it did not belong to the strata in the immediate vicinity, but had been carried there during the period of erosion that destroyed the upper part of the strata in these places.

The first locality where I found this material was on the south side of Cherokee Creek, five miles from its mouth. There was found only a single piece about 3 feet long and 2 feet in diameter. It was on the side of a hill composed of the massive limestones of the Carboniferous. There were other evidences of drift in the large pebbles found there.

The only other piece was found a few miles north of Brady. This was near a bed of conglomerate composed of small siliceous pebbles, having an iron matrix, and overlying the Carboniferous. At this place the fragments of what appeared to have once been a single tree lay scattered over the surface of the hill for a hundred feet or more. This piece must have been of gigantic proportions, some of the pieces now being four or five feet long and two feet in diameter. It will require closer examination of these woods than I was able to give in the field to determine their character. These woods may assist in determining the time at which the erosion was made and the conglomerate deposited.

CAVES.

Caves are very numerous in the limestones of the Carboniferous, and some of them are very extensive. Very few of them have been explored for any purpose other than idle curiosity. I entered only one of them, and traversed it about three-fourths of a mile. Sometimes the roof would be high over-

head, and then again we would have to crawl upon our hands and knees. There were lateral openings at different places, but we kept in the main opening. Most of the way the bottom was dry, but here and there a pool of water would be found standing in a basin of calcareous rock. Stalagmites covered the floor and stalactites hung from the top. We came to a place where there was a descent of the bottom of the cave for several feet, and lowering our candles into the opening, found on account of the gas they would not burn, so we retraced our way to the entrance. This cave is in the massive limestone, three miles down the Colorado River, on the west side from the Sulphur Spring, and just below the mouth of Falls Creek.

Other caves have large quantities of guano in them, deposited by the bats. Some of these deposits are twenty feet thick, and are of unknown extent. These caves will in the near future no doubt be fully explored, and their valuable beds of guano put upon the market.

CONCLUSIONS.

The sections made at the various localities mentioned, which can not all be published at this time, warrant the following conclusions:

1. The lowest Carboniferous beds (omitting the Burnet marble and lithographic stone strata, which may prove older) consist of blue and black shales and limestone, with a strongly marked and persistent band of thinly bedded black limestone, containing a highly characteristic and distinctive fauna. This seems to skirt the northern border of the Silurian, from Indian Bluff, Lampasas County, to Brady Creek, McCulloch County, as a fringe, and has no great width.

2. This is overlaid by a series of sandstones and shales with little limestone, containing coal measure fossils throughout.

3. This in turn is overlaid by a series of limestones, clays, and sandstones, with probably two seams of coal 24 to 28 inches in thickness.

4. The coal measure strata are overlaid to the southwest by Permian sandstone, limestone, and shales.

5. The conglomerate found in the coal fields of the more northern part of the State appears here also, scattered over the surface in larger or smaller pieces.

ECONOMIC GEOLOGY.

COAL.

There are three seams of coal in the Carboniferous formation, as observed in this part of the country; only two of these will in any probability be of commercial value. One of them, the lowest, is found on the Scurlock survey,

six miles west of the town of Trickham, in Coleman County. The following section made in the vicinity of this coal will show the surroundings:

No.		Feet.	In.
1.	Sandstone	4	
2.	Yellowish clay	10	
3.	Bluish clay	8	
4.	Limestone, massive	4	
5.	Clay	8	
6.	Fire clay	2	
7.	Coal		28
8.	Fire clay		10
9.	Bluish clay	20	
10.	Massive sandstone	8	
		67	2

There has been some prospecting done in this vicinity, but not of a very satisfactory character. The coal outcrops in several places in a ravine and in the bed of Home Creek. This coal is of a sufficiently good quality to be of economical value, provided it can be found to extend over sufficient territory, which I think is quite probable, and may be decided by proper examination and exploration. This seam was seen again two miles east of Waldrip, at Chaffins' mine.

At this place the coal is 20 inches thick and is immediately below the massive limestone. It is of excellent quality and has been mined to some extent by following the seam under the hill from the outcrop.

The second seam of coal is that found on Bull Creek, in Coleman County, a few miles northeast of the town of Waldrip, in what is known as the Gibson shaft. In the vicinity of this shaft I made the following section:

		Feet.	Ins.
1.	Limestone	3	
2.	Sandstone	10	
3.	Clay	40	
4.	Sandstone	3	
5.	Shaly limestone	2	
6.	Clay	6	
7.	Coal		10
8.	Slate		2
9.	Coal		24
10.	Fire clay	2	
11.	Sandstone	3	

The coal outcrops in several places in this vicinity showing a variable thickness. In places the seam is almost entirely cut through by "horse backs" from the under side.

One-half mile west of the town of Waldrip, at the Finks mine, the section given on page 153 was made:

This shaft is 84 feet deep. A tunnel has been driven from the main shaft for a distance of 40 feet and a considerable amount of coal taken out, of very fair quality. The mine is not now worked. One mile northwest of this shaft is a shaft sunk by Williamson. This seam of coal shows to be only ten inches thick; and two miles southwest of the Finks mine the coal was again found to be only ten inches thick.

I doubt very much if this seam of coal will be found of commercial value on account of its want of uniformity of thickness over any considerable extent of country.

GAS.

Natural gas has been found in boring wells for water in a number of places in the country covered by the present expedition. This gas is from the same shales that produce the oil, that of the lower Carboniferous. In the well of Mr. L. L. Shields, of Trickham, the gas rises to the surface with the water and oil. If the water be pumped out of the well, the gas rises in such quantities as to produce a noise when rushing out of the well. One mile west of Trickham the salt water and gas were reached at a depth of 280 feet. The flow of gas at that place is said to be stronger than from the well at Trickham. The gas at this well was lighted with a match, and burnt with a continuous flame, sometimes as high as 20 feet.

Three miles southwest of the town of Waldrip, in McCulloch County, on the south side of the river, on the farm of Mr. John Kellett, at a depth of about 80 feet a flow of salt water was obtained, and with it gas in sufficient quantities to burn continuously when lighted.

The gas is without odor, and is no doubt in sufficient quantity to be of economical value. There being a supply of salt water flowing from the same wells that furnish the gas, the gas could be utilized in the manufacture of common salt.

It is probable that gas might be obtained at some of the towns in this part of the country in sufficient quantity to be used for lighting the streets, if not for other purposes. At a depth of about 500 feet it is probable a flow of gas would be found at the town of Lampasas.

Four miles south of San Angelo, on the farm of Mr. Nasworthy, there is a flow of gas from a well 325 feet deep. The gas is probably found with the salt water, which was obtained at a depth of 80 feet. This stratum of salt water ought to be reached at the town of San Angelo at about 150 feet.

OIL.

Oil has been found in several places in the country over which I have recently traveled. The most notable place is at Trickham, in Coleman County. A well on the premises of Mr. L. L. Shields in that town was put down to the depth of 220 feet. At a depth of 100 feet salt water was reached, which flows from the top of the well. With the water is brought up oil, which collects on the top of the water. This oil has never been analyzed, and has not been collected in any considerable quantity. It has been used for lubricating purposes. It is found in the lower part of the Carboniferous. Mr. J. H. Finks, of Waco, is now drilling another hole only fifty feet away from the first, for the purpose of testing the quantity of oil to be obtained.

The same oil-producing stratum was penetrated and oil obtained at Brownwood. The shales producing this oil are found at the surface near Lampasas, McAnnelly's Bend, near San Saba, and westward to near the town of Brady. Whether the oil will be found in quantities sufficient to be of economical value, is not yet determined. This determination will have to be arrived at by penetrating the oil-bearing stratum at different localities, and possibly at a more remote point from the line of outcrop.

Oil has been found in several places, in small quantities, oozing from the ground, but never in sufficient quantity or under circumstances that warrant particular mention.

IRON.

I have only seen two places during the expedition where there is any probability that iron ore can be obtained in sufficient quantity to be of economical value. The first place is on Cherokee Creek, two miles northeast of the town of Cherokee, on the lands of Mr. J. T. White. The ore is in the Silurian limestone, and is a brown hematite in stalactitic form. Considerable ore is scattered over the surface of the hill, and I traced the deposit for several hundred feet. A small amount of money judiciously expended in prospecting would determine the quantity of ore to be obtained in that locality.

The other place is on the San Saba River, a mile below the mouth of Brady Creek, in San Saba County. At that place there is a fissure in the massive limestone partly filled with iron ore. This fissure is from 18 to 30 inches wide. I traced it in a northeastern direction about half a mile. This ore is brown hematite, and the only question is as to the quantity. The ore seems to be continuous for some distance, and the vein is easily traced by the scattered ore on the surface.

ARAGONITE.

This mineral was found by me in only two localities in sufficient quantity to be of any use; yet I do not doubt that it can be found in other localities equally as abundant as at the places mentioned below.

One of these places is on the lands of Mr. D. N. McRea, about fifteen miles west of the town of Lampasas, near the north line of Burnet County. It occurs in a fissure in the massive limestone of the Carboniferous formation. It is very compact and much of it is beautifully banded. Some of it when fractured has a dark resinous color. It takes an excellent polish, and can be obtained in slabs large enough for table tops.

Another locality is in San Saba County, on the south side of Cherokee Creek, five or six miles from its mouth. This has about the same geological position as at the former locality, and the material is about the same as that from Lampasas County, only it seems to be a little whiter and the crystals are smaller. This material is used largely for making ornaments, and is generally known when polished as "Mexican onyx." It is not an onyx, but is simply a carbonate of lime crystalized under a peculiar form. It does not differ in composition from calcite.

STRONTIANITE.

This mineral is found in beautiful crystals on the head of Little Lucy Creek, six miles north of the town of Lampasas, and elsewhere in that vicinity. It also occurs at the head of Lynch's Creek, twelve miles northwest of the town of Lampasas.

At both these places it is imbedded in the limestones of the Cretaceous formation. It is found on Lucy Creek at two horizons about twenty feet apart. In the lower it is in massive nodular form, and is in a bluish limestone. At the upper horizon it occurs in geodes, with crystals of dog-tooth spar. Some of the crystals are beautifully tinged with blue, and are almost perfect crystals. Other crystals are clear white. This mineral is used in the manufacture of nitrate of strontia, which is used for making red color in fireworks. One nodule was obtained weighing forty-three pounds.

Another locality where this mineral was seen was near the head of Lynch Creek. It occurs in this place also in the Cretaceous formation, and is associated with crystals of calcite. None of the material at this place had the beautiful blue tinge that gives value to the crystals for cabinet specimens. It is probable, however, that such crystals might be found upon diligent search.

BUILDING STONE.

There is an abundance of building stone in all the counties, and in nearly

every neighborhood good stone for building purposes may be had within a convenient distance.

Very few quarries have been opened to any extent, and those only to supply a local demand; and besides every builder has opened his own quarry, and its location was determined more by the nearness of the quarry to the edifice to be constructed and the convenience for quarrying than anything else.

The stone suitable for building purposes may be had in all the formations examined, but is more abundant in the Cretaceous and Carboniferous than in the Silurian.

A particular description of the stones found at various localities will give an idea of their fitness for building purposes.

Everywhere on top of the Cretaceous is a bed of hard limestone, ranging from 2 feet to 10 feet in thickness. The bed is sometimes divided by a thin stratum of siliceous shell conglomerate, and when that is the case, there is a difference of structure in the stratum above and below the shell conglomerate. This is Mr. Robt. T. Hill's "Cáprina limestone." (See his report.)

These two classes of stone are found in the quarries near Lampasas, where they are both used extensively for building purposes. One of them is more compact and is whiter than the other, and, as a matter of course, is more desirable. They are both easily quarried, and are soft when first taken out, but harden on exposure to the atmosphere. So durable and compact is the upper stratum of this rock that it is extensively used for the bases of tombstones, for which purpose it is shipped to different parts of the State. It is also used extensively for facings in buildings erected of other material. This stone is easily dressed when taken from the quarries, having no siliceous material in it whatever. These same beds are found on the top of the Santa Anna Mountain, in Coleman County, where it has been quarried and shipped to various localities. They are also found on top of the Brady Mountains, in McCulloch County; but, so far as I am informed, no quarry has been opened at that place.

They are found on top of the hills west of the town of San Angelo, in Tom Green County. These stones have not been used very extensively at this place, for the reason that the Permian sandstone and limestone are more convenient to the town, and are said to be more easily worked—at least such is said of the Permian sandstones.

The sandstone of the Carboniferous is found in many places, and has been used in preference to any other when it could be obtained. I first found it on this expedition near the head of Lynch's Creek, in Lampasas County. No use has been made of the stone there except for building chimneys. It is there found in layers from 1 foot to 4 feet thick. This is a yellowish, soft,

even-grained sandstone, easily quarried and worked. It hardens on exposure, and becomes darker with the length of time exposed.

This bed of stone may be traced from where I saw it on Lynch's Creek to the head of Richland Creek, in McCulloch County, and probably farther.

This stone occurs a few miles north of the town of San Saba, where it is quarried and used for building purposes to some extent. There being a good limestone nearer to the town than the sandstone, it has been more extensively used.

At Brady City, the county seat of McCulloch County, the court house is built of a sandstone found in the vicinity. This is the same stone as at San Saba.

There are several limestones in the Carboniferous formation that will make good building material. Some of them have already been used to a limited extent in a few localities. The stones are very much harder than the Cretaceous limestones and do not harden much on exposure. They are all dark, except some of those which have metamorphosed by heat into semi-marble. These limestones vary in thickness from a few inches to several feet.

The best limestones for building purposes in the Carboniferous formation are the beds of blue limestone situated just below the beds of black shale. At that horizon there are several strata of this rock, varying in thickness from one to three feet. This stone is dark blue, and is in such even beds that there would be but little work necessary to be done if the stone was laid down in the same position it occupied in the seam in the quarry. This rock is found along Lynch Creek, in Lampasas County, and at Bend on the south side of the Colorado River, at San Saba, and the country west, underlaying the black shale. The line of the fracture is smooth, but seldom at right angles. I have seen acres of a bed of this stone exposed in blocks of uniform thickness, yet broken so as to make pieces eighteen inches wide and from two or three inches to four or five feet long. The lines of fracture and cross fracture are perfectly straight, so that a wall could be built without having to cut a single stone except those used at the ends. This stone receives a very fine polish, and is of a bluish-black color and very ornamental.

The Permian sandstone is of a bluish color and is very abundant in the vicinity of San Angelo, where it has been extensively used. It is easily quarried, and when first taken out of the quarry is easily dressed. It is even-grained, and may be had entirely without spots of iron. The stone hardens on exposure to the atmosphere. Some of this stone has been shipped to Galveston and other places for the erection of buildings.

The limestone of the Permian is quite hard, and when well selected makes an excellent building material. It is of a reddish-yellow color, and is in beds from one to three feet thick. It does not take a fine polish. It varies

greatly in quality within a short distance. The stratum that would furnish good building material at one place might be absolutely worthless for such purposes within a very short distance. A considerable amount of stone has been taken out near the old town of Ben Ficklin, four miles south from San Angelo, and used in the latter place, the public school building there being built out of this material.

MARBLE.

The stone called "Texas Marble" is nothing more than a partly metamorphosed shaly limestone, that is of no value for building purposes except for making lime. There are, however, several good quarries of marble that in beauty will rival the best. The most notable place is a few miles southeast of San Saba, and only a short distance from the Fleming Springs, where there is sufficient water to run machinery for the purpose of manufacturing the marble. The marble in this vicinity has several colors, ranging from pure white to shades of red or flesh-colored. These beds are at the base of the Carboniferous or top of the Silurian.

Another locality where the marble has been quarried is on the north side of Cherokee Creek, six miles below the town of Cherokee, near the farm of Mr. Charles Harris. The quality of this I do not think is as good as that near the town of San Saba.

It is more than probable that other places may be found where the stone will be equal in quality and abundance to that at these places.

CLAYS.

The clays suitable for economic purposes are not abundant, except for the heavier pottery and for brick-making. These are everywhere abundant. The Carboniferous abounds in fire clay of various degrees of purity. Clay for the manufacture of paints can be found in large quantities and of various colors. The localities where this kind of material can be found are too numerous to be mentioned.

There is not a town in the entire district examined where good clays for making brick cannot be readily obtained in its immediate vicinity. I have not seen any of the finer clays, yet they might occur in many places.

LITHOGRAPHIC STONE.

The lithographic stone occurs in a thin bed near the base of the Carboniferous formation. It has a general uniformity of stratification and texture. It was first seen in Hill's pasture, just east of the Sulphur Springs on the Colorado, 20 miles west of Lampasas. It was also traced along the outcrop for many miles in different localities. It was again seen in Ramsey's pasture, on the

west side of the Colorado; and again on the south side of Cherokee Creek, on both sides of the San Saba and Bluffton road. Another place at which it was observed was three miles east of the town of San Saba. In all these plaçes it occupies the same geological position. The texture of the stone is as fine as need be desired, but it has not been found in large enough pieces to be of any value. The stone has a perfect network of lines of fracture running through it. These lines are filled with calc-spar, which renders it worthless. The best was seen near San Saba. It is possible if the vein was uncovered so as to get away from atmospheric influences it might be much better; or it might be that if the deposit was traced by its outcrop from one locality to another, which might be easily done, a locality would be found where the stone would be free from these lines of fracture. The stone is of a uniform color wherever seen, being a light gray. The bed is from six to eight inches thick. When much weathered, and struck with a hammer, it splits into thin layers.

SOILS.

The soils have a very great variety of composition, and consequently of fertility, owing to the fact of their being composed of the detritus from the strata in the immediate vicinity, as well as material transported from great distances. There are no barren soils in the country, unless it be an occasional small area at the base of some hill, where the clay has been washed down and spread over the valley. These places are of rare occurrence and are of small extent

The soils of the Cretaceous and from the limestones of the Carboniferous are very black, with but little sand admixed.

The soils of the sandstone region of the Carboniferous are sandy, of a reddish color, often having a red clay subsoil. The soils of the valleys of the rivers and some of the local plateaus are a reddish loam, with different kinds of subsoil, owing to the difference in locality. Another class of soils are those along the smaller creeks, where they are made up entirely of the washings from the adjacent hills and of the vegetable and animal remains that have lived and died on these lands. They are probably the most fertile of all the lands in this part of the State. Any of these soils are of sufficient fertility to make good agricultural lands, and the only questions that need be seriously considered in selecting a location, or that need be discussed, are the questions of rainfall and possibility of irrigation.

The soil of the Lampasas River is principally from the adjacent Cretaceous strata. There has been at some time a large amount of water flowing down these valleys, bringing in the sands and other material from a distance, making a black sandy soil of great fertility, and which annually produces fine

crops of wheat, oats, and cotton, as well as vegetables of all kinds. These valleys are overgrown with sumach and other smaller brush and vines.

The timber is principally elm, burr oak, hackberry, wild china, and pecan. This valley below the town of Lampasas can be easily irrigated.

The uplands of Lampasas County are the black and gray soils of the Cretaceous. The lands are fertile and produce abundant crops of wheat, oats, corn, and cotton. They are principally prairie. Along the creeks and branches there is some post oak, blackjack, and live oak timber. On some of the high hills there is cedar.

Many places in the county where the Carboniferous limestones occur, the soils have a reddish tint, commonly known as mulatto lands. For a few miles east of the Colorado River there is a belt of country that is quite rocky; and while the soil is very fertile, the rocks which lie scattered over the surface render it unfit for agricultural purposes It is excellent land, however, for grazing, and it has more timber than the other lands.

The sandy lands made from the sandstones and shales of the Carboniferous formation are on the north side of Lynch Creek, in the northwestern part of Lampasas County. They are reddish in color, with a subsoil of red clay. These lands are overgrown with post oak and blackjack timber. They are easily cultivated and are quite productive. It is not probable that they will stand the drouth as well as the more compact soils, but with enough rain they produce good crops, and this is the case nearly every year.

The bottom lands of the Colorado River are a red sandy loam, and have been made by the drift brought down from the country higher up the river. They owe their reddish color to the material brought down from the red clay beds of the Permian formation, situated a hundred miles to the northwest, through which the river runs. This soil is rendered fertile by the admixture of gypsum with the other material. This material is from the great gypsum beds found near the headwaters of the Colorado River. These lands are easily cultivated, and produce abundant crops. They are level enough in places to be irrigated; and it will be easy enough to take the water out of the Colorado River for that purpose, if it shall be thought advisable to do so.

The soils along Cherokee Creek are mostly derived from the decomposition of the black shales and limestones of the Carboniferous, and from the sands of the Silurian, found on its upper waters. They are generally of a reddish color. The hills on either side of the creek are covered with cedar. Some of the lands on the higher valleys are made from the material of the strata of the surrounding hills, and have less sand, and are much darker in color. This is fine wheat land, and is equally good for all other crops. The soils of the country situated within the Silurian formation are more sandy and of a redder color, the red sandstones of that formation giving color to

these soils. In the greensand of the lower Silurian occurring in this part of the country is found the source of their great fertility. The valleys are overgrown with large pecan timber, as well as burr oak, walnut, and elm. On this kind of soil I found the largest sumach trees I have ever seen anywhere. Some of them on the lands of Mr. J. T. White, near the town of Cherokee, are ten inches in diameter. On the high hills of the Silurian limestone there are extensive thickets of shin oak brush.

The soils of the San Saba River are generally dark, and are the result of the disintegration of the limestones, shales, and sandstones of the Carboniferous. They are equally as fertile as the soils of the Colorado. The timber is about the same as that of the Colorado River. The valleys are level and suitable for irrigation.

The soils along Richland Creek are much the same as those along the San Saba River. This creek runs along the line of contact between the limestone and the sandstone of the Carboniferous. The soils are sometimes reddish and sometimes black, owing to the side of the creek on which they are situated. The black soils are mostly on the south side of the creek, while the reddish soils are on the north side. The reddish soils have much more sand in them than the black, yet they seem to be of about equal fertility.

The high level plateau between the San Saba River on the south and Richland Creek on the north is generally black, with more or less sand. It is principally derived from the black shales of the Carboniferous. The timber on this plateau is live oak and mesquite.

To the northward of Richland Springs are the sandy post oak lands of the Carboniferous. At Putnam, in the northwestern corner of San Saba County, the Colorado River is again reached, and the same classes of soils exist as were found in Lampasas County. The valleys are broader and the timber not so abundant. The soil is redder, and has received less material from the surrounding hills. The valleys are here overgrown with large mesquite and live oak timber.

The soils about Trickham are in broad plateaus; some of them prairie, and some overgrown with mesquite. They are made from the sandstone and limestones of the Carboniferous. The creek valleys are broad and generally black sandy soil. Some of the lands are overgrown with post oak and blackjack timber, and in addition to these, in the bottoms, are large pecan, elm, and burr oak trees

The soils in the country about Santa Anna, in Coleman County, are generally a reddish sandy loam. They are sometimes a dark sandy soil. They are made from the strata of both the Cretaceous and the Carboniferous formations. They get their reddish color from the reddish clay of the Cretaceous and the red clay of the Carboniferous. The sand also comes both from the

Cretaceous and the Carboniferous. The lands are generally prairie, with an occasional live oak scattered here and there. The soils are fertile, and produce good crops of wheat, oats, corn, and sorghum. These soils are particularly adapted to raising the sorghum cane. Mr. G. W. Mahoney, four miles south of Santa Anna, says that in the dryest year that has been in the last eight years, he grew sorghum fifteen feet high. He was cutting his wheat when I visited his place. It would average thirty bushels per acre. These soils need deep plowing in the fall and deep planting in the spring, and then as little cultivation during summer as possible. If the ground is broken deep in the fall, and the seed planted deep in the fall or early spring, according to the variety, there is no danger but what there will be good crops of wheat or oats raised.

West of Home Creek, on a high level prairie, the soil is black waxy with "hog-wallows." It looks much like some of the black lands farther eastward.

The country between Waldrip and Brady Mountains is generally a high level prairie, with mesquite brush. The soil is a reddish sandy loam. The crops in this belt of country were in excellent condition, there having been good rains during the entire season. The soils from the Brady Mountains to Brady Creek are blacker and are not so sandy. They contain more lime.

The soil on Brady Creek is black sandy and is very fertile. There is no chance to irrigate these lands, unless it should be done by making dams and storing the surplus water.

The largest body of level land seen on this trip is what is known as the Lipan Flat, and is situated partly in Concho and partly in Tom Green County. It is between the Cretaceous hills on the south and the Concho River on the north and west. The body of land is from 15 to 20 miles wide and 30 miles long. It is so situated that it could nearly all be irrigated by making a dam near the head of the South Concho River and storing the surplus water, as well as utilizing the water of the river.

The soils of this flat are of various colors. Generally it is a black argillaceous soil and is quite fertile. If these lands could be irrigated there are none which would yield greater returns.

The lands of the Concho rivers and their upper tributaries, Dove Creek, Spring Creek, and others above the red beds of the Permian, are black and very fertile. They are made from the Cretaceous strata and the vegetable deposits which have grown on these lands for ages past. Large amounts of these lands are under irrigation and the crops are abundant. Fine crops have been raised this year on some of these lands without irrigation.

What can be done by thorough cultivation of the uplands in this country without irrigation may be seen from a description of the Riverside farm, situated two and one-half miles northeast of San Angelo, and owned by

Lasker and Lerch. On this farm there are 200 acres in cultivation. Two years ago they broke the land and put it in condition to plant. On the 29th of March they finished planting 4000 fruit trees, consisting of apples, pears, peaches, plums, apricots, cherries, nectarines, and almonds. These trees are all growing nicely, not more than five per cent of the whole number having died. Some of the trees bore a small amount of fruit this year. There are also raspberries, blackberries, gooseberries, and strawberries. On the farm are 72 varieties of grape vines, all showing a vigorous growth. The crops consist of corn, wheat, oats, barley, rye, clover, millet, sorghum, cotton, and flax. There is also a great variety of vegetables growing.

The crop of 1888 gave an average per acre of 40 bushels of corn, 45 bushels of oats, and one-half bale of cotton. The present crop promises to be equally as good. The plan of cultivation on this farm is to break the ground deep in winter and plant deep and cultivate often with shallow plowing. The soil on this farm embraces every variety found in the country.

WATER.

There is no scarcity of water for domestic purposes in any part of this district. There are a great many springs, and wells are easily obtained at moderate depth. There is only one place where any trouble has been experienced in getting water, and that was just after leaving Richland Springs, in San Saba County. In places there they have to go 100 feet or more to get water in their wells. There are probably more large springs in San Saba County than any other county in the State. No less than sixteen of these springs occur in this county, and the smallest will not run less than 200 gallons per minute; and besides these there are innumerable smaller springs in different parts of the country.

Water for stock purposes is abundant everywhere—in the rivers, in the springs, and in the creeks. At only a few places has it been found necessary to construct tanks for supplying stock water.

The water in nearly all the springs and wells mentioned is measurably free from impurities.

Water for driving machinery is found at several localities but has been used only in a small way for that purpose in a few places.

There are small areas in different places where shallow water can not be obtained. The localities are near the outcroppings of the thick clay beds, and where the overlaying gravel and sand beds are too thin to be water-bearing, but these areas are very small and are entirely local.

ARTESIAN WELLS.

The conditions for obtaining artesian water are very favorable in every

part of the territory I have examined. The strata are composed of alternat ing beds of sandstones, shales, and clay beds. The sandstones and shales of the Carboniferous formation are generally of sufficiently open structure to allow the passage of water through them. Then there are also shaly limestones that will prove good conductors of water. The strata of the Silurian will also be found a good water-conducting formation.

There is a gradual dip of these strata to the northwest in both the Silurian and Carboniferous, and there is sufficient elevation to the southward to bring the water to the level of the surface in the northwest, at least as far as the country covered by this examination. Artesian water obtained in the Silurian will sometimes be free of salts, and again will be highly impregnated with mineral matter. I do not think it probable that fresh water will be obtained anywhere in the Carboniferous. At least none of the water already found in any of the wells has been free from salts.

A well at Trickham gives flowing water at a depth of 100 feet. The water is too highly impregnated with chloride of sodium to be used for domestic purposes, and other salts may or may not be associated with it which would render it unfit for making common salt.

One mile west of Trickham, in Coleman County, there is another well in which water was reached at a depth of 280 feet, which rises to the surface and would probably flow if suitably cased. The water in this well is about the same as at Trickham. Three miles southwest of the town of Waldrip, in McCulloch County, is a well in which flowing water was reached at a depth of 80 feet. The water is highly impregnated with chloride of sodium, and has a small percentage of iron in the form of ferrous carbonate. An analysis shows that it has no other ingredients in it that would be deleterious in the manufacture of common salt. In a well belonging to Mr. John R. Nasworthy, four miles south of San Angelo, that is 325 feet deep, salt water was reached at a depth of 80 feet. The well is not cased, yet the water rises to the surface. This water is quite salty, enough so to be excellent for the manufacture of common salt, unless there should be impurities contained therein. This could be easily determined by analysis.

No wells have been put down below the strata of the Carboniferous to test the water of the Silurian. As the artesian water at Waco, Fort Worth, and other places is found in the Cretaceous strata, and has its origin east of this country, it is useless to expect to find the same water here.

MINERAL WATERS.

Mineral waters are abundant, and are found both in springs and in dug or bored wells at various depths. Some of these latter are artesian or flowing wells. The most notable springs are those at Lampasas, which have

long been famous for their medicinal qualities. As early as 1868 the writer spent a summer at these springs. At that time there were no hotel accommodations, and the visitors brought along their camp equipments and pitched their tents under the shade of the trees. The bath house was a temporary structure, made of canvas over the principal upper spring. An occasional raid in the vicinity by the Comanche Indians kept the visitors most of the time in the camp. Now everything is changed. The railroad brings hundreds of visitors every year. Large and commodious hotels with modern improvements and conveniences are there; the grounds have been enclosed and the natural growth of trees trimmed; a large and convenient bath house has been constructed, where one can have either a hot or cold bath, as his inclination or necessities may require; a street car runs from one spring to the other, the two being situated about one mile apart, and everything is done to make the stay of the visitors pleasant. Invalids and visitors can secure such accommodation as their ability to pay for will warrant.

There are two principal springs. The Hanna Spring is the one farthest east, and is on the east of and nearest to the town. It has a flow of 2500 gallons of water per minute, and a temperature of 71 degrees Fahrenheit. These waters are variable in the amount of mineral salts they contain, and they alternate in these changes. When the Hanna Spring is highly impregnated with salt, the Hancock Spring is weak; and when the Hancock Spring is highly impregnated the Hanna Spring is weak. They are evidently both from the same source, and owe these periodical changes to the flowing into them of water from other sources than that which furnishes the salts, in variable quantities at different times.

The following analysis was made of the water from the Hanna Springs by E. Waller, Ph. D., of New York, per United States gallon of 231 cubic inches:

Ingredients.	Grains.
Chloride of sodium	49.835
Bromide of sodium	trace
Bicarbonate of lithia	0.186
Bicarbonate of lime	24.282
Bicarbonate of iron	0.052
Chloride of magnesium	18.265
Chloride of calcium	8.040
Sulphate of potassa	2.024
Sulphate of lime	3.462
Alumina	0.059
Silica	0.496
Organic matter	trace
	106.701

Both of these springs come from a fracture in the Carboniferous limestone.

Another spring, known as the Sulphur Spring, is situated on the west side of the Colorado River, in San Saba County, and about twenty miles west of Lampasas. This spring has about the same mineral qualities as those at Lampasas. It is near the bank of the river, and issues from beneath the massive limestone near the base of the Carboniferous. I had no means of estimating the amount of water flowing per minute. There are no improvements at this place except a very rude bath house. Numbers of people from the surrounding counties come here with their camp equipage and spend weeks during the summer months. The scenery is wildly romantic. The river here has cut its way for miles through the massive limestone to the depth of 200 feet, forming a canyon. The sides of the hills are covered with almost impenetrable jungles of cedar. A more romantic locality can hardly be found in the whole State. Any one who might desire to get away from the busy scenes of a city life and spend a week or two with only the wild scenes of nature for companions, could not find a better place than this.

Some of the salt wells in Coleman County and McCulloch County, in addition to the large percentage of chloride of sodium they contain, have also a large percentage of iron, shown by the broad deposit of hydrous peroxide of iron seen near the streams. Before reaching the surface the iron is held in solution in the water as a ferrous carbonate that is almost immediately changed into the insoluble peroxide on reaching the atmosphere. In order to get the benefit of these waters they must be used fresh from the wells. This kind of water flows from the artesian well near Waldrip, situated on the land of Mr. John Kellett.

There is a well in the town of Brady that has been used by invalids with beneficial results. No analysis of its waters has been made. A well on the Riverside farm, near San Angelo, gives water that is highly impregnated with minerals of several kinds, such as magnesia, potash, etc. In fact, in almost every neighborhood in the country covered by the Carboniferous formation there are wells or springs highly charged with minerals, varying in different quantities and in different combinations.

SALT WATER.

Water containing a large per cent of chloride of sodium is abundant throughout the country occupied by the lower part of the coal measures. Some of the wells are flowing, and in some the water comes very near to the surface, and would probably flow if proper efforts were made by casing in a suitable manner. Some of these waters contain as high as 7.5 per cent of common salt, without any other undesirable ingredients. In the

dryness of the atmosphere of this country water evaporates very rapidly, so that large amounts of salt could be made from these flowing wells with but little expense. The flowing wells at Waldrip and San Angelo are samples of what may be obtained at almost any locality embraced within the Carboniferous formation. I have not made an estimate of the amount of water flowing from any of these wells, nor of the amount that it is probable they would furnish by pumping, but am sure there is no lack of water in abundance. A few miles from San Angelo salt water is found very near the surface. Some of the waters have ingredients that would render them unfit for the manufacture of common salt, but the suitability of water for this manufacture can be very readily determined by analysis.

WATER POWER.

There are a number of places where the water could be used for driving machinery, and where it seems only a question of a very short time until it will be so used. It is estimated that the four springs at Lampasas will furnish about 10,000 gallons per minute. The creek below the springs has a fall of fifteen feet per mile, so it will be seen at once that a considerable amount of power could be had within a short distance of the town. This would be a favorable locality at which to establish manufactories of different kinds. It would be a fine locality for a cotton or woolen mill, or for both.

The fall in the Colorado River anywhere below the mouth of the San Saba is great enough within a short distance to give sufficient power to run heavy machinery, and in many places a dam could be constructed at no very great expense, as the material with which to build such dam can be had in the immediate vicinity.

The falls at the mouth of Falls Creek are 105 feet perpendicular. The water comes from a spring in the vicinity, and in sufficient amount to give large power.

The springs which flow into Cherokee Creek give sufficient water to supply a large power. At only one place, so far as learned, has the water been used for this purpose. Mr. J. S. White, who lives one mile and a half east of Cherokee town, has put in a dam four feet high across the creek, by which he has turned the water into a race three hundred yards long, where he has a turbine wheel which runs a corn mill and cotton gin.

Near the mouth of Cherokee Creek there is a fall of 18 feet in 900 feet. With the amount of water usually in Cherokee Creek this would be sufficient to produce a large amount of power.

Rough Creek, which runs into the Colorado River a few miles above Cherokee Creek, has enough and constant water to make it a stream of importance in a small way. There is now a small mill and cotton gin run by the

water. There is sufficient water to run much larger machinery than is now being used.

The spring at San Saba is used for driving the machinery of a flour mill of 250 barrels capacity per day. At a short distance below the mill, on the same stream, is the dam for the waterworks. The Fleming Spring could be utilized for working the beds of marble in the immediate vicinity, without losing any of its value for irrigating purposes.

The San Saba River has a succession of falls from head to mouth. At almost any locality there could be constructed a dam that would furnish water sufficient for a large amount of power.

The Concho River has a fall of about fifteen feet to the mile. All the rivers are fed by large springs at no great distance above the town of San Angelo. This water could be very easily made to furnish a large amount of power for manufacturing purposes. This would be a good place to start a woolen mill, as a very large amount of wool finds its market here every year. No city or town of any size can flourish without manufactories; and cheap motive power is always to be taken into account in the estimates of a manufacturing enterprise. Water power is always the cheapest that can be used, when it is convenient, so there is no reason why the immense power that can be derived from the waters of the Concho River in the vicinity of San Angelo can not be used in the way indicated. It has been estimated that there is water enough in the river on the Riverside farm to give 380 horsepower.

IRRIGATION.

The question of irrigation is one so intimately connected with the farming interest in this part of the State that every available supply of water and every locality of suitable land for this purpose ought to be investigated. With this idea before me, I have given this matter particular attention during the present expedition. While it is not absolutely necessary to the raising of crops that the land shall be irrigated, yet the value of the product may be greatly enhanced thereby. There are two sources of water supply; one is the utilizing of the natural supply from springs and streams already in existence, and the other is to make large reservoirs for the storage of the surplus waters of the creeks and rivers. The many large springs and the perennial streams of this country have been examined with this in view, so as to give some definite idea of the adaptability of all of them to the purpose of irrigation. The first place examined with reference to irrigation was Lampasas Springs. Here there is a constant and unvarying flow of water from the several springs of 14,400,000 gallons per day. All this water can be very easily taken out of the channel and turned on the wide val-

leys below. In the first three miles below the springs there is a fall of 46 feet. The valleys of the stream are broad and level, so that there would be no trouble in getting water over the entire space. The soils are well adapted to the purpose of irrigation, being black sandy, with a subsoil that would retain moisture for a considerable length of time. Although this water is largely mineralized when first issuing from the springs, it is not found to be detrimental to the growth of crops, nor does it injure the land after having gone a distance of a mile or two in an irrigating ditch. There is land enough subject to irrigation in the valleys below to consume all the water furnished by these springs. This water might also be taken out of the Lampasas River at other places than immediately below the city. The water might be first used in driving machinery for manufacturing purposes near the town, and afterwards taken from the channel and used for the purpose of irrigation.

There are several springs along Cherokee Creek that might be used in a small way for irrigation; or the creek might be taken as a whole and used upon some of its broad valleys. The Cherokee Springs, at the head of the creek, furnish a large amount of water, and at a very small expenditure the water could be carried to the broad valleys below. Already a dam has been constructed across the channel below one of the springs, and at a small expense of a few hundred dollars it could be extended so as to include the water from both springs. This water is fresh, and the springs are constant in amount of water they furnish.

The Fleming Spring, three miles east of the town of San Saba, furnishes water to irrigate at least 300 acres of land if properly distributed. It issues from beneath the massive limestone at about the same height as the valleys. Already a part of the water is being utilized for irrigating purposes. At one time it was the intention of a former owner to use all the water from the spring for irrigating his farm, but he was restrained from doing so by an action brought against him by the owners of land below him on the creek made by this spring. A large part of the water now goes to waste.

The Hubbard Spring, a mile northeast of the Fleming Spring, is well situated for irrigating purposes and furnishes about the same amount of water. It is also used in a small way for irrigation, but the most of the water runs to waste. There is plenty of land in reach of this water to consume it all by irrigation, but the riparian rights of the owners of land below on the stream have been asserted.

The large spring just east of the town of San Saba, which is now used for driving machinery in the flouring mill and the water works, furnishes a sufficient amount of water to irrigate several hundred acres of land, but is permitted to run into the river after serving the before mentioned purposes. A

small amount is taken out at the upper dam and turned into a garden and a small field.

On the lands of Mr. Sloan, ten miles west of the town of San Saba, and on the south side of the San Saba River, a fine large spring bursts out from under the massive limestone rocks. This spring and branch made by it to the junction with the San Saba River are all on the lands of Mr. Sloan, so there is no one to set up a claim of riparian rights; hence all the water from this spring has been used to irrigate his fine farm of several hundred acres.

The Richland Springs, at the head of Richland Creek, in the western part of San Saba County, furnish enough water to irrigate several hundred acres, but the water has never been used for this purpose. These springs occasionally, in very dry times, go dry, but not until after the crops are matured. The lands are good and of such a character as to be well adapted to irrigation. There are sixteen of these springs in San Saba County, and all of them might be used for irrigating the lands in their immediate localities.

The Colorado, San Saba, and Concho rivers can all be utilized for irrigating their broad valleys and the adjacent plateaus.

The Colorado River would be the most difficult to divert from its channel, as the lands are generally much above the bottom of the channel. The valleys are of sufficient extent anywhere above San Saba County to consume all the water of the river, and are very fertile.

The waters of the San Saba are abundant, and no trouble would be experienced in taking the water from its present channel and conveying it to the valleys above. The valleys are broad and fertile. They now produce fine crops of corn, wheat, oats, and cotton without irrigation, but this yield would be greatly increased by irrigating. There is less need for irrigation along this river and in San Saba County than in any of the counties over which my observations have extended.

The Concho rivers and the country adjacent thereto are more adapted to irrigation than either of the other rivers in the district described. The river is more constant in its supply of water and the plateaus of level land above the lower valleys are more accessible.

The South Concho River, Dove Creek, Spring Creek, and North Concho River all have their source at the foot of the Staked Plains. They all have very large springs at the head. None of these springs has a flow of less than 2000 gallons of water per minute. Irrigation ditches have been taken out on all these streams, and thousands of acres are already under irrigation. In none of these streams has one-half of the water been utilized. The system of irrigation, if it can be called a system, is of the most primitive kind. The farming is mostly done by Mexicans, for a share of the crop. Every man takes out what water he wants, and for as long a time as he wants it, letting

the remainder flow back into the channel. The next man below him has built a ditch and taken out the water, and so on to the end.

Such is the character of the soil of these streams that they retain a large amount of moisture after having the water from the irrigating ditch spread over them, and numerous springs have broken out along the banks of the river since the plan of irrigating the lands has been put in operation; and instead of the water from the river being exhausted by taking it out and spreading it over these valleys, it is really stored for constant use. There is as much water in the river below the irrigated farms now as there was before there was any water taken out. There is really more water now in the Lower Concho River than there was before these irrigated farms were made. The only reason that can be assigned for this fact is that heretofore all the water was allowed to flow down the channel during the rainy season, and at all other times, while now the surplus water is taken and spread out on the valleys above and forms reservoirs and supplies numerous springs with water which before only flowed during wet weather.

The advisability of storing the surplus water need not be discussed in a report like this. The only questions that need be considered are whether it can be done successfully, and the places where such storage can be made to advantage. It would be a very easy matter to find places along the San Saba River where dams could be made from one hill to the other and an immense amount of water be saved for future use. This river runs from head to mouth through the massive limestone of the Silurian and Carboniferous formations, and it would be difficult to find a place where the water could be stored in reservoirs except along the immediate channel of the river, owing to the height of the surrounding country.

It would be more difficult to store water in the channel of the Colorado River, on account of the material over which it flows and the character of the soil in its immediate valley; but when once the water is taken from the channel it could be conducted to localities where immense lakes might be formed and water stored for future use.

The clays of the Carboniferous formation are impervious to water, and places could be selected where these clays would form the bottoms and sides of artificial lakes of immense size. When the time comes for selecting localities for water storage, there will be no trouble to find such places to store the immense surplus of water that at times goes down the Colorado River.

The Concho River furnishes the best locality for utilizing or storing surplus water of any of the rivers of this region, owing to the ease with which the water may be taken out of the channel, and the extensive plateaus which lie contiguous to that stream.

It is possible to make an immense reservoir for the storage of water a few

miles below the head of the South Concho River, and the water could be taken out and used to irrigate the Lipan Flat, a body of land containing at least half a million acres. The lands in this flat are so situated that this water could be taken to any part of them. There is not a better place for such an enterprise in the State.

RAINFALL.

The amount of rainfall necessary to successful agriculture without irrigation varies in different parts of the United States. Much more depends upon the distribution of the rainfall than upon the annual amount of precipitation.

In California, the rainy season is from December to April, and the annual precipitation in inches is given at less than 20.

In Dakota, the rainfall is in the spring and summer, and is given at 15 inches annual precipitation.

In California agriculture is entirely dependent upon irrigation, while in Dakota the rainfall is sufficient to be useful in raising abundant crops without the aid of irrigation. The following table of rainfall, taken from the record kept at Fort Concho from 1868 to 1889, shows that there have been about four years in which the annual rainfall was below 15 inches; and in the dryest year the rain fell from April to July, the months when it was most needed for agriculture. In 1888 excellent crops were made in the arid regions of Texas, and the record shows the rainfall to have been 22.08 inches. Of that amount 13.28 inches fell from April to August. In the first five months of 1889 the rainfall has been 9.97 inches, which has been as much as desired and the crops never looked better.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1868	.....	.....	.....	3.27	4.10	.40	7.30	1.86	2.35	6.40	3.75	1.69
1869	2.55	.20	2.41	1.10	3.31	3.76	.43	1.94	.50	.96	1.59	1.60
1870	.16	.16	4.76	.62	.26	4.36	3.32	6.90	9.92	5.44	1.24	.12
1871	.....	.54	2.75	1.90	4.40	.42	.....	2.04	.90	2.78	.44	.20
1872	1.28	1.20	.....	1.12	1.86	1.50	3.79	2.60	.85	.66	1.66	.53
1873	.16	.33	1.60	.....	4.56	6.40	.92	1.46	.44	1.08	.25	.....
1874	.25	.25	1.14	.39	3.29	3.05	.88	.61	5.58	.64	2.92	5.80
1875	.05	1.75	.12	.50	1.70	.64	5.67	.22	1.22	....	.36	2.47
1876	1.00	.32	.36	.50	.....	1.52	.78	3.14	2.84	....	.52	.68
1877	....	.98	.30	.79	2.12	1.47	.50	2.32	3.60	1.50	1.00	2.00
1878	.....	.10	.....	2.32	.02	1.50	4.55	.....	6.70	.....	1.10	.....
1879	.50	.....	.40	1 70	1.10	3.80	.50	4.00	1.00	.20	.....	.....
1880	3.90	.60	1.14	1.70	1.15	3.20	7.60	3.90	7.20	2.50	.30	.60
1881	....	...	.20	1.46	6.10	.10	.40	.20	.70	2.30	.50	1.80
1882	.84	3.38	.35	.09	1.23	2.09	4.14	8.46	3.59	.58	2.05	....
1883	.....	.....	3.16	.....	.....	.76	3.39	2.20	3.36	6.04	.50	.60
1884	.40	.80	.50	4.60	9.08	1.87	2.20	.96	2.00	4.76	1.86	6.21
1885	1.32	2.15	1.35	3.91	2 33	4.22	1.08	1.35	1.90	.75	.....	.70
1886	.15	.80	.75	.48	.76	1.60	.36	3.74	.56	1.35	.....	.....
1887	.....	.10	.....	1.76	2.86	.66	.93	1.88	2.81	1.74	1.36	.98
1888	1.10	1.98	.92	3.63	1.55	2.50	3.10	2.50	.48	1.72	2.20	.40
1889	1.94	2.57	1.15	2.03	2.28	.....	.....	.....	.....	....	...	.....

TEMPERATURE.

The temperature of a district is dependent largely upon the altitude and latitude. As the question of temperature is one that is to be considered in determining the adaptability of a country to agriculture, a table of the temperature is here given, the observations having been made at Fort Concho:

Year.	January.			February.			March.			April.			May.			June.		
	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.
1868	.....	.....	....	.....	.....	....	.....	.....	....	98	36	67.20	101	55	80.03	107	57	76.56
1869	75	24	45.93	85	28	50.47	96	33	57.46	92	36	63.98	101	45	79.37	98	55	78.06
1870	84	19	41.70	74	19	49.83	89	25	55.84	90	35	65.17	98	59	72.82	98	63	82.41
1871	78	12	44.58	93	27	53.57	95	35	59.08	101	32	69.04	102	43	73.12	102	66	78.00
1872	79	13	40.98	81	22	49.60	87	30	54.74	90	37	64.88	102	42	74.56	102	58	81.50
1873	80	2	45.00	82	18	54.24	96	30	61.47	94	31	68.83	99	44	73.50	100	66	67.62
1874	80	18	46.50	82	28	53.50	84	35	57.39	91	34	64.67	99	51	79.92	104	72	81.18
1875	71	0	37.43	78	4	43.63	92	38	67.76	95	47	69.06	107	51	77.10	105	56	80.20
1876	79	31	51.16	86	19	52.44	88	19	34.24	98	34	69.36	101	45	76.35	104	56	80.17
1877	78	14	45.64	87	24	53.18	84	30	61.84	89	35	63.70	97	42	72.91	104	50	80.50
1878	74	8	43.62	84	10	49.74	88	29	57.71	98	40	67.18	96	45	73.26	102	58	82.72
1879	76	3	46.28	87	11	49.35	92	19	63.76	94	31	66.31	101	50	78.95	102	48	83.34
1880	80	15	57.23	66	15	50.21	86	14	58.52	97	25	71.49	98	46	76.61	101	52	84.81
1881	82	6	37.96	78	16	47.58	86	26	58.32	96	32	66.84	90	48	73.17	106	59	81.88
1882	71	18	46.57	77	31	55.71	89	28	61.90	95	30	68.16	94	52	74.08	103	57	83.61
1883	78	3	41.87	81	5	45.90	84	26	57.41	94	31	62.98	103	48	77.35	105	54	78.14
1884	73	5	38.04	82	17	46.85	89	26	58.97	95	32	61.56	93	44	69.82	100	53	83.05
1885	74	2	39.35	79	15	45.64	90	30	54.61	99	42	67.18	93	45	71.09	107	62	84.63
1886	80	3	39.51	78	17	50.15	87	24	60.94	93	30	68.80	107	50	81.14	112	60	81.14
1887	84	5	43.51	84	14	50.42	95	29	60.86	101	34	67.78	101	43	74.60	107	64	82.07
1888	79	1	40.84	79	28	50.34	91	24	51.78	94	43	66.13	98	51	97.43	104	58	....
1889	75	21	46.32	81	17	50.08	85	35	57.20	94	44	69.11	98	43	72.13	.....	.....	....

Year.	July.			August.			September.			October.			November.			December.		
	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.	Max.	Min.	Avr.
1868	112	65	87.50	111	64	88.10	107	49	79.12	96	40	66.31	87	32	38.30	90	24	47.74
1869	100	65	74.53	108	70	83.26	110	43	71.81	102	32	57.68	102	28	60.68	84	12	48.96
1870	100	63	80.99	101	76	81.12	95	61	75.87	96	43	68.60	98	27	49.62	80	7	41.04
1871	102	72	87.19	102	68	84.85	90	50	74.85	90	38	65.47	81	23	51.84	80	13	44.72
1872	100	65	82.95	102	60	85.25	102	47	78.83	97	33	65.69	82	18	52.01	80	20	42.15
1873	102	64	80.86	102	61	83.09	107	50	81.60	101	34	70.00	86	31	57.02	73	31	48.85
1874	105	73	88.42	105	70	84.31	103	50	75.96	96	40	67.70	97	27	60.01	76	28	48.50
1875	104	59	80.31	104	53	81.87	100	48	76.87	96	41	69.12	92	23	56.46	80	28	52.78
1876	110	63	84.83	113	66	83.35	101	48	76.10	91	42	65.61	82	29	50.80	74	9	39.16
1877	104	56	84.43	103	63	83.48	100	49	77.59	98	30	66.07	77	15	49.90	71	15	47.55
1878	100	50	82.89	99	56	83.90	91	41	72.94	93	27	66.82	83	15	54.88	74	8	39.64
1879	107	66	88.79	101	57	79.44	101	51	73.11	91	32	68.89	87	13	57.47	84	0	49.86
1880	101	55	83.09	96	47	78.91	98	44	74.85	88	32	64.78	78	8	43.28	82	2	34.06
1881	106	60	86.66	101	64	86.13	98	58	80.52	90	40	71.19	88	32	56.04	76	21	31.13
1882	109	65	83.89	97	58	78.46	90	47	72.51	88	42	62.26	89	25	56.60	78	17	44.31
1883	102	65	84.23	101	38	80.48	98	43	73.16	96	35	66.83	87	10	52.76	82	0	47.28
1884	110	68	82.76	103	73	84.06	101	63	81.68	95	42	62.37	80	30	55.69	82	10	46.98
1885	103	65	83.44	105	62	84.28	96	56	77.33	94	36	61.89	88	25	56.84	75	15	51.10
1886	112	68	86.21	105	65	86.72	95	51	76.20	89	39	67.18	85	22	53.03	76	8	45.80
1887	106	68	86.52	103	63	93.26	100	45	78.66	92	34	62.69	83	21	52.78	73	12	42.26
1888	102	67	86.47	111	61	86.95	98	53	77.48	93	41	67.72	90	28	53.06	75	29	52.13
1889	.....	.....	....	.....	.....	....	.....	.....	....	.....	.....	....	.....	.....	....	.....	.....	....

It must be remembered in consulting the above table that the high temperature shown does not produce the same effect upon vegetation or animal nature that the like temperature would produce at a lower altitude and one where there was little breeze. In this country the atmosphere so rapidly absorbs the moisture of the body that the heat is not as oppressive as where the absorption is not so great. Such a thing as sun-stroke has never been known in this part of the State.

The following table will show the course of the wind from 1886 to 1889, kept by the signal station at Fort Concho, Texas:

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1886.												
N.	4	3	3	1	2	...	...	2	3	7	8	11
N. E	2	1	4	...	5	3	4	1	1	2	6	6
E.	5	2	5	...	1	2	1	5	2	1	1	1
S. E.	1	3	1	4	6	6	5	6	4	4	...	1
S.	5	4	9	11	10	15	7	11	12	6	4	1
S. W.	6	5	6	6	7	4	6	5	3	1	6	4
W.	3	1	...	5	...	...	5	1	1	5	3	3
N. W.	2	4	3	3	...	...	3	...	4	8	1	4
1887.												
N.	4	2	...	2	1	3	4	6	5	8	...	9
N. E	3	1	1	3	1	2	1	4	2	2	5	5
E.	1	5	4	4	3	1	2	1	...	...	1	...
S. E.	6	4	5	1	4	3	4	5	...	3	3	1
S.	7	1	6	7	14	11	10	6	9	8	3	1
S. W.	1	7	1	5	2	4	5	7	5	3	1	4
W.	6	1	7	6	1	7	1	4	1	4	5	6
N. W.	2	3	5	4	4	1	5	...	7	6	4	5
1888.												
N.	3	2	6	1	4	7	1	6	5	2	6	8
N. E.	6	3	...	...	1	3	1	4	3	5	1	6
E.	1	4	2	...	1	...	3	1	1	6	5	1
S. E.	2	4	3	6	3	...	5	3	7	1	4	3
S.	3	1	9	17	10	11	9	4	7	6	3	2
S. W.	9	5	4	4	5	5	6	5	1	7	6	4
W.	4	6	1	2	..	1	5	4	7	2	4	4
N. W.	3	4	6	1	7	3	1	6	...	4	1	3
1889.												
N.	3	1	7	3	2	...	...	...	..	...	...	...
N. E.	5	2	...	4	1	...	...	...	...	...	...	...
E.	1	5	5	1	4	...	...	...	...	...	...	...
S. E.	4	3	1	1	7	...	...	...	...	...	..	...
S.	5	3	8	10	16	...	...	...	...	...	...	...
S. W.	6	4	1	8	..	...	...	...	.	...	...	...
W.	1	8	7	1	...	...	...	...	...	...	...	...
N. W.	6	2	2	2	1	...	...	...	...	...	...	...

TIMBER.

The timber in the district examined is in sufficient quantities for all economical purposes, except for building houses, unless it be in the extreme western part of the country. The different kinds are post oak, pecan, hackberry, cottonwood, elm, water oak, shin oak, cedar, live oak, mesquite, and white china. The most important is the cedar, which is to be had in almost unlimited quantities along the Colorado and San Saba Rivers, as well as on Cherokee and other creeks. The post oak is found almost everywhere in that part of the country occupied by the Carboniferous sandstone as far west as Camp Creek, in Coleman County. Along all the creeks and rivers there is plenty of timber for firewood. The mesquite is of almost universal growth. The larger mesquite trees make excellent fence posts, and there is no better wood

for domestic purposes than dry mesquite. It is a rapid growth, and where the fire is kept away, in a few years a growth will be made sufficiently large for firewood. In some places farther west, the roots of the mesquite compose the only kind of firewood to be had, and it is very little more trouble or labor to get a load of roots out of the sand than it is in many places to get a load of wood above ground.

In the San Saba River bottoms are to be found some very large burr oak trees. I measured one near the town of San Saba that was four feet in diameter. It was straight and twenty-five feet to the first limbs. This was not an isolated tree, but stood in the midst of a forest of others almost as large.

The pecan trees are found along every creek and river, often in great numbers and of large size. Their chief value now is not in the excellent timber they afford, but for the abundance of nuts they bear. The growth of timber is everywhere rapidly increasing, and will so continue where it is protected from fires.

The fencing is almost entirely done with posts and wire. The posts are made of cedar found so abundantly along the Colorado River and shipped in car loads to the place needed. In other localities the mesquite is used for posts. In other places the live oak and other oaks are used for this purpose.

THE

PERMIAN OF TEXAS

AND ITS

OVERLYING BEDS.

BY

W. F. CUMMINS.

THE

PERMIAN OF TEXAS AND ITS OVERLYING BEDS.

W. F. CUMMINS.

It is only intended in this report to give a resume of the work done* in the Permain formation in Texas, as well as an outline of the leading characteristics of the formation as I have observed them, and also to draw some conclusion in regard to the economics of the district, leaving to a future report the work of giving these facts a fuller and more extended explanation.

The Permian formation in Texas embraces all that territory situated between the Coal Measures on the east and the base of the Staked Plains on the west, except a line of disconnected hills extending from Comanche County to Big Springs, ranging along the south side and almost parallel with the line of the Texas and Pacific Railroad. These hills, at least in their upper members, belong to the Comanche series of the Cretaceous. There are also a few isolated hills north of the line of the Texas and Pacific Railroad, such as the Double Mountains in the western part of Stonewall County, whose tops are capped with the rocks of the Cretaceous.

The extreme southern limit of the Permain formation in Texas is a few miles south of San Angelo, in Tom Green County. In that locality it is only a few miles wide. It is covered on both the east and west sides in that vicinity by the Cretaceous. The formation widens constantly to the northward, until at its broadest part it is not less than 150 miles wide.

The stratification is conformable with that of the underlying Carboniferous and has a general dip to the northwest.

The area underlaid by these beds is, as one would naturally suppose from the character of materials of which they are made up (mostly sands and clays, with interbedded sandstone and limestone), a beautiful rolling country, cut here and there by smaller or larger creeks or rivers, with little timber save along the streams, with broad valleys in places, and at others precipitous canyons. Only where the heavy bedded limestones of the middle division

*The observations on which this brief statement is based have extended over a period of nearly ten years, although the closer stratigraphic study was mostly done during the field season which has just closed. Previous to that time my investigations were carried on at various places, and not connected by direct observation, as has now been done.

occur, or in the massive gypsum deposits of the upper beds, do we find any bluffs of considerable height.

This formation was first reported as Permian, in 1852, by Professor Jules Marcou, who was at that time geologist with the Pacific Railroad Survey, from Fort Smith to the Pacific Coast.

In 1868, Dr. Wm. De Ryee, in a report made for the Texas Copper Mining and Manufacturing Company, and published by them, reported the red beds of Archer County as Permian. Prof. Jacob Boll, formerly of Dallas, Texas, in an article entitled "Geological Examinations in Texas," published in the American Naturalist (Vol. XIV, pp. 684, 686, September, 1880), called these red beds Permian. Since that time Prof. E. D. Cope, of Philadelphia, Pa., has described, in the American Naturalist and elsewhere, many vertebrate fossils coming from these beds as Permian species. Dr. G. C. Broadhead also refers some of the beds at Colorado City to this series. Dr. C. A. White, of the United States Geological Survey, published in the American Naturalist (Vol. XXIII, pp. 109–128, February, 1889), an article describing the invertebrate fossils of the Permian that had been collected by myself while collecting vertebrate fossils for Prof. E. D. Cope, and also those collected by him from localities which I pointed out during a five days trip in that field. This, except a few smaller notices, is all that has been written on this subject.

The estimated thickness of the strata of the Permian is about 2800 feet. A detailed section has been made across the formation, but a general section has not yet been made up so as to determine the exact thickness of the strata.

The dip of the strata is about 40 feet per mile north 45 degrees west. At one locality the dip was calculated by an actual instrumental measurement of ten miles, and at another place of five miles, and at a great number of places of smaller distances, so that the dip of the strata is well determined. It is only at the western edge of the Double Mountain beds that there is any increase in the dip, and in that locality the strata are so much distorted and folded that it was difficult to get long lines of observation, so that the general dip could be determined with anything like certainty. There were no faults found nor any evidence of eruptive disturbances.

For convenience the strata are here divided into three beds, whose correlation with the Permian formation in other localities will not be attempted in this report.

Beginning with the lowest or eastern, we have:

1. The Wichita Beds.
2. The Clear Fork Beds.
3. The Double Mountain Beds.

These beds, from the nature of their constituents and of their formation, so grade into one another that the exact line of demarkation is very obscure,

even if it can be found at all. This is no less the case with the line between the Permian and the underlying Coal Measures. A separation of these series from the Coal Measures is, however, based, first, on lithological differences; second, on fossil contents.

The strata of the Coal Measures are not persistent in character on the line of contact between that formation and the overlying Permian; and yet in each locality there seems to have been a continuous sedimentation. On the line of contact between the Coal Measures and the Wichita Beds, from Red River south to the Brazos, there are only sandstones in both strata; yet there was a considerable lapse of time between their deposition, as is shown by the fact that the limestones, which at other places constitute the highest beds of the Coal Measures, and which at those places overlie the sandstones, are entirely wanting along the line of this contact. Further south, on the line of contact between the Coal Measures and the Clear Fork Beds there are only limestones, which are apparently continuous in sedimentation, yet we know that such is not the case, for only a few miles north of this line of observation we find that the Wichita Beds of the Permian underlie these Permian limestones.

The fact of the want of continuity of sedimentation between the Coal Measures and the Clear Fork Beds is shown also by the fauna of the two beds. The fauna of the Coal Measures limestones, which lie directly below the limestones of the Clear Fork Beds, is abundant, and consists of such characteristic forms as *Productus semi-reticulatus*, *Chaetetes gracilis*, *Schizodus wheeleri*, *Allorisma sub-cuneata*, *Hemipronites crassus*, etc., but they almost fade out before they reach the top of the series, and only a few species pass up into the overlying limestones of the Permian, and other species of newer type take their places. The same may be said of the fauna on the line of contact between the Coal Measures and the Wichita Beds.

The Double Mountain Beds do not reach the Coal Measures at any point, but lie conformably upon the Clear Fork Beds. The Clear Fork Beds are the only ones that reach the southern extremity of the Permian district.

The Permian Beds are overlaid on the west by the Jura-Trias (?) and Cretaceous. It is evident from the remaining buttes and ranges of Cretaceous hills that the entire Permian and Carboniferous strata were at one time covered by the Cretaceous, at least along the southern portion of the district. Erosion has again removed these strata and exposed the older beds.

THE WICHITA BEDS.

The Wichita Beds are the lowest in the series, and are composed of sandstones, sandy shales, clays, and a peculiar conglomerate. The sandstones and sandy shales are red, gray, and variegated, often containing large oval con-

cretions, ranging in size from one-quarter of an inch to several feet in diameter. The sandstones are often shaly in structure, while in other places they are massive. They are often ripple-marked and at other places have a cross-bedded structure. The concretions are very hard, and retain the peculiar structure of the sandstone in which they occur. The clays are red and bluish. In the red clays are nodular masses of clay, iron, and lime, which often take the form of geodes, filled with tabular lime-spar in the center. The bluish clay is copper-bearing in many places. The conglomerate is composed of rounded pieces of clay or clay ironstone, cemented together by iron. Fossils occur in all these beds, which consist mostly of plants and vertebrates, very few invertebrates being found. The largest number of the vertebrates described by Prof. E. D. Cope were taken from the Wichita Beds.

THE CLEAR FORK BEDS.

The Clear Fork or Middle Beds of the Permian are composed first of bedded limestone, magnesian, and earthy, which are sometimes carbonaceous enough to be classed as stink stone. These carry a large and characteristic fauna. They are in turn overlaid by clays and less fossiliferous limestones and shales. The limestones become less fossiliferous towards the top of the beds. The clays are both red and blue, the former color largely predominating. The red clays are in thick beds and are in places interstratified with sandy shales. There are also beds of white, red, and spotted sandstones. Toward the top the beds become more sandy, and a few seams of gypsum occur, but not in the quantity in which it is found in the Double Mountain Beds. There is also the peculiar kind of conglomerate which has been described in the Wichita Beds. The red clays contain vertebrate fossils, the bluish clay has copper, and the limestones have large quantities of invertebrate fossils.

The fossils mentioned by Dr. White in his article heretofore quoted, published in the American Naturalist, were taken principally from the Clear Fork Beds. By reference to the list it will be seen that it embraces both paleozoic and mesozoic types, and some that are peculiar to and characteristic of the Permian. It will be seen from the list that the broad shouldered *Brachiopods*, which were so abundant in the coal measures, are wanting.

THE DOUBLE MOUNTAIN BEDS.

The Double Mountain or Upper Beds of the Permian are composed of sandstones, sandy shales, limestones, red and bluish clays, and thick beds of gypsum. The limestones are quite earthy, and are often very full of the casts of fossils, the newer types largely predominating. The shales are

often highly impregnated with common salt, and none of them are free from gypsum. The sandstones are red, gray, and spotted, and are generally very friable. The gypsum beds are numerous and often very thick, and the seams of fibrous gypsum traverse and transect the clays and shales in every direction, ranging from paper-like seams to those ten inches in thickness, and often making a perfect network of seams. Towards the western boundary of these beds the strata are much distorted and folded. It looks as if there had been a heavy lateral pressure from the west, crumpling the strata into short folds. In the gypsum the folds are often only an inch or two across.

During the progress of this expedition, and since the publication of Dr. White's article, I have found in the Clear Fork beds a few specimens of a *Productus*. I have also taken a few new species from the different beds which are yet to be described.

The last of the *Orthoceratites* occur in the limestones of the Double Mountain beds. In that bed the mesozoic types largely predominate.

The vertebrate fossils described by Prof. E. D. Cope in his several articles were taken entirely from the Wichita and Clear Fork beds, principally from the former. The species described by him was each peculiar to the horizon from which it was taken, except in a few instances. Out of about fifty species taken from these beds and described by Prof. Cope, not a half dozen come from both the Wichita and Clear Fork beds. This number may, however, be increased upon further observation. The fossil vertebrates found in these beds embrace fishes, batrachians, and reptiles. Very few of them were known to science until taken from these beds and described by Prof. Cope.

The flora of these beds is yet undescribed, but enough is known of it to see that some of the characteristic species of the Permian are contained therein. It is intended to have the specimens of plant remains which have been collected from these beds placed in the hands of a specialist for examination and identification.

OVERLYING FORMATIONS.

DOCKUM BEDS.

A few miles before reaching Dockum, situated in the western edge of Dickens County, I came upon a bed of conglomerate sandstone and red clay, resting unconformably upon the clays and sandstones of the upper Permian, entirely unlike anything I have heretofore seen in Texas. This formation lies along the foot of the Staked Plains in a narrow belt. Because of its extensive occurrence in the vicinity of Dockum, I gave the formation the name of Dockum Beds, but will not for the present attempt to determine their cor-

relation. I have found everywhere on the beds of the Permian belt pieces of conglomerate and large pebbles of white quartz that did not belong to the Trinity sands of the Cretaceous which were supposed to overlie the Permian to the westward, and it is a matter of interest to know where this drift came from. The fragments of conglomerate increased in size as we traveled westward until we came upon the beds of that material in the vicinity of Dockum, and the question was solved as to the origin of the fragments of conglomerate and the quartz pebbles.

In the conglomerate are many silicified trunks of trees, some of them of great length. In the red clay above the conglomerate are fossil remains of large reptiles, whose species I was unable to determine in the field. In the upper sandstone were many casts of a *Unio* that I have provisionally called *Unio documensis*. In most places that fossil occurs only as casts, and in one place only did I find specimens of both valves, and they were so badly incrusted with carbonate of lime that the peculiar markings of the shell could not be seen. The sandstone was everywhere full of scales of mica, some of the scales being one-sixteenth of an inch square. The whole thickness of this formation in this vicinity is about 150 feet. These beds extend under the Staked Plains. I traced them up Blanco Canyon to the falls of White River, where they pass out of sight under the beds of the overlying strata.

There are a great many springs of clear pure water flowing from these beds, and wherever the formation has been penetrated by wells, an abundance of good water has been obtained.

BLANCO CANYON BEDS.

Overlaying and resting unconformably upon the Dockum Beds are beds of red clay, white sandy clays, white clays, and a hardened clayey limestone, fronting to the eastward and forming bold escarpments 200 feet high. These beds constitute the Staked Plains. Because of the extensive presentation of these strata in Blanco Canyon, Dickens County, I have given them the name of Blanco Canyon Beds. The strata have a very slight dip to the southeast. A distance of twenty-five miles gave an average dip of eight feet to the mile. The surface is almost level, except where it is traversed by deep canyons. These canyons occur only at wide distances.

The only fossils found in these beds were some of the larger mammals and a species of turtle. Enough was found to show the strata to be of much more recent date than the Cretaceous which is found at the foot of the Staked Plains farther southward. Blanco Canyon takes its name from a butte on the west side of the canyon, twenty miles from its mouth, which is capped with a white clay with the appearance of chalk. White River, a beautiful stream of clear water, flows through the canyon, fed by numerous bold springs

and lateral streams on its west side. For twenty miles from its mouth the canyon is from one to three miles wide, and is bordered everywhere by precipitous bluffs 200 feet high. In only a few places is it possible to get down these bluffs on horseback, and for twenty miles there are only two places where a wagon can be taken down.

ECONOMICS.

Especial attention has been given to the study and collection of soils and the soil-making material from this district, with direct reference to their adaptability to the production of the ordinary crops. It has been thought that this part of the State was not adapted to agriculture, and that an attempt to open farms would be time and labor thrown away. In order that the Survey may be able to give definite information on this subject, the character of the soils has been investigated.

Nothing is intended in this report more than a general statement of the prominent characteristics of the different soils in the district, leaving the more detailed statement to be made after having the soils analyzed and studied.

There are three principal kinds of soil in this district, classed by their derivation rather than by their chemical properties. The first are those derived from the immediately underlying strata, and have only such foreign ingredients as have come from the decomposition of the vegetation growing upon them from year to year. (Residual soils.)

The second class are those having in their composition such material as has been brought from other localities; they were deposited during the time of the great erosion and have derived very little if any of their material from the strata upon which they rest. (Soils of transportation.) The third class are the soils along the rivers and larger creeks, and are derived from the other soils and the later erosion of strata along the different courses of the stream. (Alluvial soils.)

The first class are purely local, and do not extend over very wide areas in any one locality. They vary in composition and color according to locality. Where they are derived from the massive friable sandstones and clays they are quite sandy and have a deep red color. In such localities the color and composition have been very little changed by vegetable deposits. In the limestone belts, where the origin of the soils is due to the decomposition of the limestones and the accompanying bluish clay beds, the soils are dark and in places are quite black. They have a good deal of vegetable material in their composition, and owe their dark color largely to this fact. All of this class of soils are more or less sandy. These are generally the best grass lands.

The second class of soils are by far the most abundant in the region under consideration. They are very homogeneous in color and composition, yet in places they have been changed in both respects by their immediate contact with the underlying strata.

In considering the composition of this class of soils it will be necessary to remember that several hundred feet of material has been eroded and carried away or redeposited. During this period of erosion the waters probably spread out in broad sheets. These waters were heavily laden with the materials gathered up on their way, the materials being precipitated to the bottom on any decrease in the rapidity of the flow of the waters.

Afterwards the rivers and creeks cut through these deposits in various directions into their present drainage basins, and left the deposits as they now are in broad, high, level plateaus. The overlying strata destroyed by this great erosion were several hundred feet of the lower Cretaceous formation, composed of sand beds and limestones, and several hundred feet of the Permian strata, composed of sandstones, limestones, clay beds, and gypsum. Still further northward the beds that have been called Blanco Canyon Beds, composed of sands and white clays, were involved in the erosion. The material derived from all these beds was mixed into a homogeneous mass and deposited, making the broad level plateaus. The soils of these plateaus will therefore be composed of the white clays and sands of the Blanco Canyon Beds, the clays, sands, and limestones of the Cretaceous, and the sands, clays, and gypsum of the Permian.

It will be seen from a glance at the composition of these soils that they are derived from such a variety of sources that they are likely to contain the ingredients necessary to the composition of first-class soils. Experimental tests, which after all are the best sources of information, have proven that they will produce abundant crops of wheat, oats, and corn. In Baylor and Wichita counties, where this soil largely prevails, the average crop of wheat was over twenty-nine bushels per acre. I mention these two counties because they are the only localities where I have personally examined the matter of crops, and they are fair representatives of that part of the State in the way of soils. The thickness of this class of soils ranges from a few inches to many feet, owing to the undulating and uneven surface of the underlying strata at the time of their deposition. The surface is very often so level that the height will not vary over five feet in a mile. It might be supposed from this statement that the soils would be unfit for cultivation for want of drainage, but such is not the case. There is so much sand in the soil that the water is soon taken up and none left on the surface, and therefore no surface drainage is necessary. Water is always found in wells at the base of these soils, and by capillary attraction they are always kept moist.

The third class of soils might very well be classed as a variety of the second class, as the most of their material has been brought from a different locality than that where they are found. They were, however, deposited by different agencies, and are somewhat different in composition. They contain more clay, and consequently are of a very red color. They are found along the present courses of the rivers and creeks, and might with propriety be called bottom lands. There is ordinarily more timber on them than upon either of the others. Where these lands have been put into cultivation they have proven of equal fertility with any others in the district. They usually do not lie in as large bodies as does the second class of lands mentioned in this report.

Soils that are derived from one stratum are very often lacking in some essential ingredient that goes to make up an ideal soil, and this must be supplied by artificial means. Soils formed as these are contain all the principal ingredients necessary in a good soil. In a word, they are all that could be desired for agricultural purposes and will not be easily exhausted.

FERTILIZERS.

The principal fertilizers to be obtained in this district are the gypsum and gypseous marls found principally in the Double Mountain Beds of the Permian. These occur everywhere in inexhaustible quantities wherever those beds are found. Their value as a fertilizer is very great, and if upon analysis the soils should be found lacking in the qualities which these substances furnish, it will be no great task to supply the missing quality.

The gypsum occurs in all conditions of purity, from the pure transparent selenite to the more massive varieties. The beds are often 25 feet thick, and are the most abundant rocks in the Upper Permian.

WATER.

It has already been said that in many places the country is well supplied with water. No difficulty has been experienced in any locality in getting water in shallow wells ranging from 20 to 50 feet in depth. Other wells have been sunk to 100 or more feet, where a still greater amount of water was obtained. The water is generally impregnated with carbonate of lime, and in the Double Mountain Beds it is all impregnated with gypsum.

Stock water is furnished by the rivers and creeks, and by tanks constructed in such localities as are too distant from the natural supply of water for the cattle to reach them and return to their pasturage.

RAINFALL.

After the question of soils that of the rainfall is, to the agriculturist, the one of most importance. No matter how good the soils of a country may be, if the rainfall is too small, or comes at the wrong time of the year, it would be impossible to raise crops without irrigation.

There is an idea extant that this belt of country is within the arid district, but such is not the case; the eastern boundary of that district is west of the western part of the Permian formation. I will be prepared to give full statistics of the rainfall and temperature of this part of the State in a later report. It is enough to say now that there have been but few seasons in the last twenty years when there was not enough rain to mature the crops, especially the wheat crop. It will be shown by these statistics that the rains come as a general rule in those months when most needed by the farmers for agricultural purposes. The proper cultivation of the soil so as to utilize the rain when it does come is a matter of very great importance in a country where there is not a surplus of rain. If the farmer does not attend to the cultivation or breaking up of his land until after the spring rains, he is likely to need rain and not get it at a time when it is most needed for maturing his crops; but if he will break up his land in the fall or winter, and break it deep, and be ready to plant at the proper time, whether the rain has come or not, when the rain does come his crop will grow, and all the subsequent rain will be used in its growth and maturity. Such crops will have to be planted as will mature the earliest in the spring, unless they will stand the drouth of summer and then mature with the fall rains.

Wheat can be raised with profit, and will be the surest crop, as it is the earliest to mature. Oats will also be a good crop, yet is likely to be short straw. Sorghum is always a good crop, and when sown for hay gives an abundant yield.

BUILDING MATERIAL.

Sandstones and limestones suitable for building purposes are found in the Permian in great abundance. There is not a county explored that has not or could not have a number of good quarries. The sandstones of the Wichita Beds have been used extensively at Wichita Falls and Henrietta. The limestones are very abundant in the Clear Fork Beds, and have been used in several of the towns situated in that part of the district. The quality of the limestones is very suitable for building purposes. The towns of San Angelo, Ballinger, and Seymour are largely built of this kind of stone, where stone is used. Many private residence throughout the country are built of this stone,

and in the construction of the railroads which pass over these beds this stone has been used in the building of piers for the bridges. The ease with which the rock can be quarried, and the fact that it needs so little dressing, make it very desirable building material.

There are also some very good sandstones in the Clear Fork Beds; some of them have been used at San Angelo, Benjamin, and other places. There is no lack of good building stone anywhere in the entire Permian district within a short distance of any given locality.

A great many of the limestones will make good quick-lime, and sand is abundant everywhere, so that no trouble need be had in getting good mortar.

Clays for making good brick are also abundant everywhere, and many of the towns are principally built of brick made in their immediate vicinity. The bricks are of a bright red color, and are of good quality when properly burned.

TIMBER.

The timber is mostly confined to the valleys of the creeks and rivers, except the mesquite and cedar. There is plenty of wood for domestic purposes, and the cedar and mesquite furnish large quantities of fence posts. The fencing is generally done with wire, and the posts are ordinarily taken from the land fenced or in its immediate vicinity. Timber will increase rapidly when the fires that have heretofore prevented its growth are kept out. It is not until the Staked Plains are reached that wood becomes scarce.

SALT.

The wide distribution of common salt throughout the upper beds of the Permian has already been referred to. That it occurs in quantities sufficient to be of economical value has been practically demonstrated at several localities; also that there are many other places where salt can be manufactured very cheaply. It is quite certain this will be done when there shall be cheap transportation from that section.

The salt occurs in massive beds of rock salt and as impregnations in the clays and waters. At Colorado City, at a depth of about 500 feet, a bed of rock salt more than 100 feet thick was found. It is probable that these beds do not extend over a large scope of country in such thick seams, but that they do occur in several localities is quite probable. At Colorado City they are manufacturing salt quite extensively from water pumped from deep wells. There are numerous salt springs throughout the entire Upper Permian. All the rivers and creeks are impregnated with salt.

A noted place for procuring salt deposited by solar evaporation is Salt Flat, in the northern part of Stonewall County, and on Salt Croton Creek, a few

miles above its junction with the Salt Fork of the Brazos River. This flat embraces an area of about 200 acres, and is entirely level, and barren of vegetation. It has been formed by the erosion of the upper strata of the surrounding country, as is shown by the bluffs on either side and the isolated conical hills here and there in the flat.

In the midst of the flat is a bold running salt spring, whose waters spread out over the surface of the flat when there is the least rise in the water, and when the waters recede there is left an incrustation of salt from one-half to one inch thick. These waters are very highly charged with salt, so that the least evaporation causes the precipitation of the salt. Along the banks of the spring branch the salt is in beds, very often several inches thick. No effort has ever been made to manufacture salt at this place except in a small way, but for a long while persons have been gathering the salt as they needed it as it was deposited on the flat.

That salt could be manufactured at this locality at a minimum cost and in large quantities is very apparent. The spring flows at least 2000 gallons per hour, and this water could be run into open vats and left for solar evaporation, needing the labor of men enough to handle the salt.

There are many other places where the same thing could be done in this part of the State, and when it will be done is only a question of time. Cheap transportation is the only thing necessary to put such enterprises on foot.

COPPER.

There are three distinct and separate copper-bearing beds in the Permian strata—one of them in the Wichita Beds and two in the Clear Fork Beds. The one in the Wichita Beds is most largely presented in Archer County and passes thence northeastward. At that locality several years ago a mining company took out and shipped to Philadelphia, Pennsylvania, large quantities of the ore. The mine was abandoned on account of the expense of shipping the ore, which had at that time to be hauled in wagons 150 miles to the railroad, and shipped from there by rail to the furnace.

The first belt of copper-bearing clays in the Clear Fork Beds occurs just west or above the lowest beds of limestone. This deposit of copper is found on California Creek in Jones County, and near Table Top Mountain in Baylor County, and other places along the same horizon. Several tons of ore were taken out in Baylor County a few years ago.

The upper bed of copper is found at Kiowa Peak, near the northeast corner of Stonewall County, at a point about ten miles west of Benjamin in Knox County, on Raggedy Creek in Hardeman County, and other places along the same horizon. The ore is very nearly the same at all these localities. It has the form of wood and yields from 40 to 68 per cent of metallic

copper. It also occurs in nodular form and as incrustations in the clay. There are no regular veins, as is the case in many mining districts, but the copper occurs in beds. It was evidently precipitated from the sea water at the time of the deposition of the clay beds. This copper will be of economic value when works for its reduction shall be erected at the mines so that low grades of ore can be used.

IRON.

The iron ore of the Permian formation is principally a carbonate of low grade; it occurs in the red clay of the Wichita Beds in concretions. The disintegration of the clays has caused these concretions to accumulate at the bases of the precipices in large quantities, and in a convenient form to be handled, if the ore, upon proper analysis, shall be found to contain sufficient metallic iron to warrant the reduction. The red color of the clays is due to the oxidation of the iron contained therein, but the amount of metallic iron in the clays is very small.

GYPSUM.

The deposits of gypsum found in the red clays of the Permian strata are the most extensive of any such beds in the United States. They are co-extensive with the Double Mountain Beds and the upper part of the Clear Fork Beds. The beds are of thicknesses varying from that of paper-like sheets to 25 feet. There are all varieties, from transparent selenite to the massive earthy kinds. Some of the beds of alabaster are very clear, and admit of fine polish. There is enough gypsum in these beds to supply any demands that could be made.

A PRELIMINARY REPORT

ON THE

COAL FIELDS OF THE COLORADO RIVER.

BY
RALPH S. TARR.

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COAL FIELDS OF THE COLORADO RIVER.

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The section covered in this report includes the northwestern portion of Lampasas County, along the Colorado River; about two-thirds of San Saba County, principally north of the San Saba River; McCulloch County north of Brady Creek; the eastern part of Coleman County, from the Colorado as far north as Jim Ned Creek; Brown County, east of Pecan Bayou; and the southeastern corner of Mills County. The greater part of this area is underlaid by rocks of the Carboniferous system, and the chief object of the work was to determine the amount of coal, its position in the series, and the relation which it and the surrounding rocks bear to each other. The object of this report is to state, in general terms, and as briefly as possible, the most important results of the work, as a preliminary report, to be followed later by a more comprehensive and detailed statement.

This portion of the Carboniferous area is bordered on the east and west by outcrops of Cretaceous rock, which overlie the Carboniferous unconformably, the dip of the former being southeast and the latter northwest. To the north the Carboniferous rocks extend away toward the Indian Territory; but just north of Coleman County a band of Cretaceous covers the Carboniferous, nearly connecting the east and west Cretaceous areas. Pecan Bayou has cut through this capping rock and revealed the Carboniferous below, thus connecting the Palo Pinto field with the southern field by a narrow neck. In the center of the Carboniferous area buttes of Cretaceous are found resting upon the Carboniferous, either as isolated peaks, as in the case of Santa Anna Mountains and Harkey Knobs; or in a broad area, as, for instance, that south of Brownwood, in the angle formed by the Colorado River and Pecan Bayou; or as in the case of Brady Mountains, in the form of a long spur connected with the main body of Cretaceous rocks.

It is plain from this and other evidence that the Carboniferous has been uncovered by the erosion and removal of the Cretaceous rocks which once buried them, and that this removal is very recent and still in progress. At its southern border the Carboniferous rests on older formations. The older Paleozoic rocks of Llano and Mason counties were the chief land areas from

which the sediments composing the Carboniferous strata were derived. Resting unconformably upon these rocks is a limestone, which is also unconformable with the true Carboniferous. These beds appear as a narrow strip, separating the Carboniferous from the Silurian, and consist almost entirely of crystalline limestone with beds of shale. The beds of the Lower Carboniferous series were formed mostly in rather deep water off the shore of an old Silurian land area, and the beds of the sea shore may yet be seen in the form of shales, and rarely conglomerates in the bays and on the headlands of the old shore line, which may be plainly traced. The dip of the beds is somewhat variable, but the average is gentle, from 1 to 2 degrees northwest. In one place the dip is 20 degrees in the same direction. There are small anticlinals and synclinals much more numerous than in the Upper Carboniferous, where they are very rare. Unless carefully mapped and studied over a considerable area, this formation might be overlooked and classed as a portion of the Upper Carboniferous. The fossils resemble those found in the true Carboniferous, though upon closer study some will undoubtedly be found to be quite different. One specimen of *Goniatites* has been pronounced by Prof. Alpheus Hyatt to be a distinctive Lower Carboniferous form.

The deceptive resemblance of fossils would at first lead to a decision that these beds are a part of the Upper Carboniferous, and this deception is increased when an actual contact occurs between the strata of the two formations. At two places east of San Saba the limestone seems to dip conformably beneath the sandstones. In both these places the dip of the strata of each series is the same. It is only when we see the section as a whole that the true relation of the two series is discovered. The San Saba River, from just above its mouth nearly to the mouth of Richland Creek, is the dividing line between the Upper and Lower Carboniferous, and this line of division is continued westward up the valley of Richland Creek. On the north side of this line is the true Upper Carboniferous, consisting at this place of a great thickness of sandstone. South of this line is the Lower Carboniferous, composed in this region entirely of limestone and limy shales. As a person crosses the region for the first time there are three possible explanations of such a relation of beds. The first is that the limestones and sandstones are interstratified; but this is quickly disproved, since in the sandstone areas there are no limestones, and in the limestone regions no sandstones. This and abundant other field evidence proves that the limestone is beneath the sandstone; and then the problem is narrowed down to two possible solutions—the two series are either conformable or unconformable. There are two proofs that they are not conformable. The dip of the limestone averages at least two hundred feet to the mile, and with such a dip any bed of limestone, as for instance the bed on the Colorado below Red Bluff, would soon

dip under the sandstone if followed a few miles to the west, and the overlying sandstone would cover it and extend to the Silurian. But such is not the case. The belt of limestone extends continuously for nearly thirty miles. In this series there are many different beds of limestone and shale, one above the other, each one of which strikes up to the sandstone and there stops.

We have, therefore, an upper sandstone formation, composed of various beds, striking southwest, and overlapping a great thickness of limestone. There is, therefore, no explanation, to my mind, but unconformability; a fact which necessarily proves a different age from that of the overlying coal measures. That they are Lower Carboniferous rather than Devonian is shown by the close resemblance of the fossils of the lower beds to those of the Upper Carboniferous. The field evidences thus seem to prove that these beds are not a part of the true coal-bearing series, but belong to an older formation—the Lower Carboniferous. The Lower Carboniferous extends from near Lampasas to some distance west of Brady, with an average width of not more than ten miles, and is the formation on which the towns of San Saba and Brady are situated. This will remove all hope of finding coal in quantity at either of these places. The conditions which existed when the Lower Carboniferous limestone series was being formed were not favorable to the formation of extensive coal deposits. Such seams of coal as those encountered at San Saba and Brady are the best that can be expected in this formation. Thin beds of an inch or two in thickness and of local extent may be found in various places in these limestones, but it will be useless to prospect for better ones.

The lowest beds of the true Carboniferous which are exposed in this part of the State are the sandstones on the Colorado, nearly west of Lampasas, in the neighborhood of Nix Postoffice. This is the beginning of a great thickness of sandstone, having, in common with all the beds of the series, a very gentle dip to the northwest. With some few exceptions of local importance, the dip is uniform in that direction. The amount of dip is difficult to estimate without accurate instrumental measurement, which will be done in time for the final report on the coal measures. A careful examination of many hundred exposures shows considerable variability in the dip. There are places where it is as great as five degrees, but such instances are rare and very local. Again the rocks are almost perfectly horizontal, or even reversed, thus dipping to the southeast. To choose between these and select the normal is a difficult task in a region of gently dipping rocks where a superficial dislocation of a few feet will reverse the apparent dip. This dip has been previously estimated at 30 feet to the mile, but this, I am confident, is entirely too small. Many measurements which I made on outcrops average much more than 100 feet to the mile, and the general appearance of

the strata shows a much greater dip than 30 feet to the mile, which would be so near the horizontal that no inclination would appear on the ordinary outcrop.

The sandstone series, which may be the equivalent of the millstone grit, has on this basis a possible thickness of 4500 feet. The Colorado flows through it from Milburn to a point 8 miles below the mouth of the San Saba River, a distance of 70 miles. The greatest cross section is 40 miles, from a point about 20 miles northwest from Lampasas to a point 5 miles south of Brownwood. East of Brownwood the upper beds of this series disappear beneath the Cretaceous, and from this place they strike southwest to Rochelle, in McCulloch County. The eastern extension is buried by the Cretaceous east of the Colorado, and on the south the sandstone beds have been eroded away from the Lower Carboniferous, so that in no place are they found actually resting on the Silurian, although they must once have done so, since the material in the various conglomerate layers is almost entirely derived from Silurian formations. The western part of Lampasas County and the entire area of San Saba County, which lies in the true Carboniferous, is underlaid by this sandstone rock, as well as the Carboniferous corner of Mills County, the southeast corner of Brown, and a strip on the eastern border of McCulloch. Owing to its characteristic development along Richland Creek in San Saba County, I propose for this division of the Carboniferous the name of "Richland Sandstone."

This great thickness of sandstone covers an area of more than 1000 square miles. In general it consists of many beds of sandstone, with occasional beds of shale, as for instance on Elliott and Antelope creeks. The various beds of sandstone are of every conceivable grade of coarseness, from the shale to the conglomerate, though the latter rock is strikingly rare. The sandstone is generally yellow and white, containing much iron, which gives the weathered rocks a deep red or yellow color. In form of bedding the sandstone presents every grade, from the fissile shaly sandstone to massive thick-bedded layers, which in weathering form immense blocks as a talus to the hills. This is strikingly shown at various places along the Colorado, particularly near the mouth of the San Saba River. The fossil remains in the Richland Sandstone division present no great range of form, but are confined almost exclusively to some of the most durable coal plants washed from the land, and these are very common.

Conglomeritic sandstone layers are very often encountered throughout the series, but they are more often fine grained, and a breccia rather than a conglomerate. The Richland Sandstone beds are terminated in the upper portion by a band of conglomerate, of variable thickness, and extending from

Rochelle northeastward to the Colorado, along Deep Creek, and just east of the town of Milburn.

At its southwestern end it is coarsely conglomeritic, and contains pebbles often weighing a pound or two. These pebbles are almost entirely well rounded flint of various colors, derived directly from the Silurian, and cemented in some places by iron and in others by silica. Near Rochelle, the conglomerate attains a maximum thickness of fifty feet, and because of its development at Rochelle I propose the name of Rochelle Conglomerate bed of the Richland Sandstone division. Traced northeastward the conglomerate becomes finer grained, is very much cross-bedded, is interbedded with layers of sandstone, and eventually becomes, near the Colorado, a conglomeritic sandstone with thin layers of conglomerate. East of Deep Creek a portion of the Rochelle Conglomerate is buried beneath the Cretaceous, an eastern extension of the Brady Mountain Cretaceous beds, and it is in this buried portion that the change from conglomerate to conglomeritic sandstone takes place. Where it is again uncovered east of Milburn it is difficult to separate the Rochelle Conglomerate from the upper layer of the Richland Sandstone. Northeast of here the conglomerate bed becomes less distinct, but it may be traced as a distinctly conglomeritic sandstone band across Pecan Bayou to the Cretaceous.

The entire area of the Carboniferous included in the Richland Sandstone division, from its upper bed, the Rochelle Conglomerate, to the Lower Carboniferous, is barren of coal measures. Thin seams of coal may possibly be found, but no beds of a paying nature are to be expected in this formation. A condition of rapid deposition with abundance of coarse sediment, accompanied by a gradual subsidence, seems to have prevailed. That coal plants were growing on the neighboring lands is proved by their presence as casts in the sandstone, and undoubtedly thin seams of coal and carbonaceous shale will be found; but the conditions which favored the accumulation of coal beds had not yet arrived.

With the close of the sandstone era, as marked by the deposition of the Rochelle Conglomerate, a condition of quiet water and finer sediment prevailed. With the new conditions a new series of beds began to be formed, and for these I propose the name "Milburn Shales." The southwestern extension of these shales is hidden beneath the Cretaceous of Brady Mountains, but in the neighborhood of Milburn they are well shown. They are capped by limestone and underlain by the Rochelle Conglomerate. Near the head of Deep Creek the lower layer is shaly sandstone with a thickness of 60 feet. This shale grades from the conglomerate below to an argillaceous shale above, and is overlaid by a deposit of clay 15 feet thick, with scattered nodules of clay ironstone. Some gypsum is also present in this layer. Above

this is three inches of fire clay and a stratum of carbonaceous shale 1 foot thick, with laminæ of true coal. The shale is composed of clay, so filled with plant impressions that their casts are found everywhere in the shale along layers. Above this comes 25 feet of sandy shale—in places a true sandstone, but in its upper and lower layers a true shale.

At Milburn, 12 miles northeast by north from this point, the following section was obtained at Mr. Eubank's place, in a well 62 feet deep. Section from below upward:

	Feet.	In.
1. Blue slates (very hard)	Unexplored.	
2. Fossiliferous blue clay (*Productus*)	1	6
3. "Horse back coal" (carbonaceous shale)	12	
4. Coal		4
5. "Horse back coal" (carbonaceous shale)	2	
6. Coal		4½
7. Blue shales	12	
8. Shaly sandstone	16	

This coal is fully 75 feet beneath the limestone, while 12 miles south of this the distance between the two is not more than 25 feet; yet they are the same layer. I am convinced that the Milburn shales are thickening to the northeast; and further evidence that the division as a whole is thickening in this direction is found by following along the strike north of the river.

At several places at Milburn and vicinity coal has been encountered in wells, but nowhere in workable quantities. There is very little chance of finding workable coal in the Milburn division south of the Colorado; but as the formation is thickening to the northeast these beds north of the river may contain coal of economic value. No prospecting has been done in this section, and nothing can be said except that the surface indications are good. Coal is certainly there, but in what quantities can only be told by the prospector's drill.

Above the Milburn division is another great barren area, consisting chiefly of limestone, which I shall call the Brownwood division. There is present in these beds sufficient salt to render much of the water from deep borings unfit for drinking purposes. The presence of salt is noticed in many of the beds of the Carboniferous, but in this belt the salinity reaches a maximum, being in some places almost a brine.

The Brownwood division will average in width about ten miles, and has a thickness of about 1300 feet of alternating sandstone and limestone. In the northern part, in the vicinity of Brownwood, the sandstone is thicker and the layers more numerous than south of the Colorado near Milburn. West of Milburn, immediately over the Milburn shales, the Brownwood beds consist of limestone, very sandy below, attaining a thickness of 100 feet, overlaid by

25 feet of sandstone, generally fine grained, though in some places conglomeritic and cross-bedded, and these in turn are overlain by nearly 1200 feet of limestone. At this point these beds are thicker than where they are first seen to appear from beneath the Cretaceous Brady Mountains. At Brownwood the beds are much more complex, as will be seen in the following section, beginning at the base:

	Feet thick.
1. The lower limestone	200
2. Sandstone	100
3. Limestone	80
4. Sandstone (chiefly shaly sandstone)	40
5. Limestone	60
6. Sandstone	20
7. Limestone	150
8. Sandstone	10
9. Limestone	640

The lowest sandstone layer (2) has been traced along the strike entirely across the Carboniferous, but all the other layers, 4, 6, and 8, thin out to the south, and are there represented by an impure yellow rusty limestone containing much argillaceous matter. The Milburn and Brownwood beds are rich in organic remains of the usual Carboniferous types. The Brownwood Beds besides being saliferous, are also oil-bearing at places, as at Brownwood and Trickham.

Above the upper Brownwood limestone begins the Waldrip coal division. Below the coal-bearing beds proper is a considerable thickness of sandstone, which like all similar formations in this area, thickens to the northeast. The lower sandstone beds at Waldrip are not more than 100 feet thick, and are chiefly conglomerate. West of Trickham it is 250 feet thick and quite uniformly a sandstone. At Thrifty, northwest of Brownwood, the sandstone series is about 500 feet thick, with some conglomerate, particularly in the lower beds. Thus in 35 miles along the strike proceeding northeast, these beds thicken to five times their original depth.

While this sandstone series forms a true portion of the Waldrip coal series, it is as far north as I have seen it quite barren of coal, though in the northern portion along the Jim Ned Creek some of the beds closely simulate coal-bearing strata, and from here northeast beds of coal may possibly be found, though this is merely an inference, since I have not personally examined the strata north of the Jim Ned.

Above these sandstone beds are the true coal-bearing strata, consisting of thin beds of clays, shales, sandstones, and limestones. The thickness of this series of strata is not more than 300 feet, and often less, and the breadth of the outcrop from one to three miles. Owing to the character of the strata,

most of which are very soft and easily washed away, the position of the beds is usually indicated by a valley of considerable width, bordered on the northwest by a bluff capped by the hard overlying limestone and sandstone. The Waldrip beds are first plainly seen on the Colorado at Waldrip, but their exact southward extension is very obscure, owing to a thick soil derived from the decay of the Cretaceous rocks of the Brady Mountains. Traced to the northeast, in Coleman County they occupy the southern portion of the valley of Bull Creek, then curve, first east then north, around the base of a bluff into the valley of Camp Creek; then in a similar way from Camp Creek to Home Creek, the valley of which it follows northward to the east branch of Hay Creek, north of the old Trickham and Paint Rock roads. From this point it follows up the valley of this branch in a northeasterly direction to the headwaters of that creek. The new Santa Anna and Brady road crosses it just north of the old Brownwood and Paint Rock road crossing. Still continuing northeast, the series of beds crosses the railroad in the valley of the Mukewater, about four miles east of Santa Anna. Beyond this the beds strike across the divide between the Mukewater and Mud creeks, and follow down Mud Creek to the Jim Ned. The further northeast extension of this series has not yet been traced.

The nature of the strata in this division, while similar at all points in so far as the general features are concerned, is very different in detail. A general section cannot be made that will apply in detail for all parts. At Waldrip, even in an area of a few miles, great variation in the order and thickness of beds is noticeable. So great is this variation that many are led to believe that there are several beds of coal, a conclusion that is not warranted by the observed facts in the field nor by numerous borings. Others explain the anomaly by supposing faults in the form of actual dislocation, but such an explanation will not account for the observed facts. Local differences in the amount of sediment deposited and possibly contemporaneous erosion of beds already deposited will undoubtedly explain most of the observed irregularities. It is possible also that some of the strata of soft clay may have been squeezed out at places and accumulated in others by the pressure of the superincumbent beds.

At Waldrip, in the shaft which has been used for working the Finks coal mine, after going through a very hard and compact limestone, 23 feet of clays and clay shales and 18 feet of slate were passed through before reaching the coal. One and three-quarter miles east of this shaft the coal outcrops; but at this place it lies directly beneath the limestone, with no intermediate clays. There is little doubt that this is the same limestone as that encountered in the Waldrip shaft, as it is the only compact limestone which could be expected to outcrop at this place. Thus 41 feet of clays disappear in less than

two miles. About a mile north of this is another coal outcrop, having 10 feet of clay between it and the limestone. In boring for coal in the same region near where coal has been found, and at a place where it would certainly be expected, the seam of coal has not been found. This marked variation in a small area is an example of what is noticed over the entire extent of the Waldrip division. The beds are very variable, both in small areas and in a general way, over the entire district. In some places the strata above and below the coal contain great quantities of rich nodular ironstone, as on Bull and Home creeks; but on the Jim Ned this feature is almost unnoticeable.

A section at the Finks mine at Waldrip, beginning at the surface:

	Feet.	In.
1. Quarternary conglomerate (loosely consolidated)	...	
2. Massive sandstone (ripple marked)	5	
3. Shaly sandstone with considerable clay	10	
4. Fossiliferous compact limestone	1	
5. Yellow clay (with nodules of pure kaolin)		3
6. Yellow fossiliferous clay	1	3
7. Blue clay rock with thin bands of carbonaceous shale and laminæ of coal	1	8
*8. Alum clays (white, yellow, and black) with white and yellow alum efflorescence	1	3
9. Hard flinty limestone	8	
10. Clays	23	
11. "Slate" (clay shale)	18	
12. Coal	2	
13. Fire clay	1	6
14. Hard slaty rock	5	

* This is above the top of the Waldrip shaft. Mr. W. H. Nichols, former owner of the mine, gave me sections 9 to 14.

At Home Creek, in the Dunson and Kingsbury pasture, coal outcrops with a thickness of 28 inches. Below the coal is fire clay, and above it are layers of clay, shale, and clayey limestones, with a thickness of about 40 feet, and this in turn is covered by about 25 feet of shale, mostly sandy shale overlaid by limestone. Owing to the peculiarity of weathering in these soft beds it is very difficult to construct an accurate section based on surface observations.

One more section in the coal beds will be given, and this at the Silver Moon mine in the Jim Ned, the northernmost point to which I have traced the Waldrip coal seam. This section was furnished by Mr. D. B. Slater, who did the work on the shaft and made careful notes of the strata passed through. Beginning at the top, the section is as follows:

	Feet.	In.
1. Soil	6	
2. Limestone		6
3. Red clay		9
4. Sandstone	2	10
5. Clay with ironstone concretions	5	
6. Fossiliferous lime shale	2	
7. Blue shale	12	
8. Hard limestone (compact)		8
9. Red clay shale	22	
10. White sandy shale	18	
11. Blue clay rock	12	
12. Coal (very irregular, sometimes a pure shale)		6
13. Clay parting (variable)		3–10
14. Coal		6–8
15. Clay parting		3–4
16. Coal (quite uniform)		8
17. Fire clay	2	

NOTE.—The clay partings are sharply separated from the coal, so that in mining the coal is obtained free from clay. The two lower seams of coal are chiefly depended upon, and they are easily mined.

Quite uniformly covering the Waldrip coal division, and generally not more than one hundred feet above the coal, is a layer of limestone, the lowest member of a series of alternating limestones, clays, shales, and sandstones which I shall call the Coleman division, on account of their splendid development in Coleman County and near the town of Coleman, the county seat. The thickness of this lower limestone is quite variable, being more than 100 feet west of Trickham; but west of the Silver Moon coal mine, near the Jim Ned, it does not exceed 25 feet.

In order to show the general character of the beds of the Coleman series the following section is given, from the upper beds of the Waldrip coal series, four miles southeast of Santa Anna, in a northwest direction, through the town of Coleman to the Cretaceous, eight miles northwest of Coleman. The construction of a section in a region so largely composed of soft clays, which by their ready disintegration hide the strata beneath, is a difficult task. It is impossible to make a direct section, and I have been obliged to interpolate largely from one side or the other of my general section line.

	Feet.
1. Compact limestone	20
2. Sandstone	50
3. Rusty limestone	25
4. Sandy shale	10
5. Pulverulent limestone	3
6. Mottled clays	25
7. White limestone	50
8. Sandstone, changing to sand limestone below	12

		Feet.
9.	White limestone	100
10.	Red clay	10
11.	White shaly limestone	25
12.	Mottled clays (red and yellow)	15
13.	Yellow clay	10
14.	Rusty limestone	50
15.	Sandstone and sandy shale	10
16.	Purple limestone	10
17.	Yellow and red clay	25
18.	Yellow rusty limestone	200
19.	Dark blue and purple clays, bearing clay stone concretions at base	10
20.	Purple iron-bearing shale	½
21.	Sandy shale	2
22.	Yellow rusty limestone with thin bands of clay and shale, in which are several bands of carbonaceous shale and coal from one to three inches thick. This formation is at Coleman	200
23.	Red clay	3
24.	Blue clay	3
25.	Clay shale	2
26.	Fossiliferous lime shale	1
27.	Sandy shale	2
28.	Yellow rusty limestone	3
29.	Blue and red clay	5
30.	Rusty limestone, with ironstone nodules	15
31.	Pink limestone	1
32.	Rusty limestone, massive	12
33.	White limestone	10
34.	Alternating yellow, blue, white, grey, and pink limestone, possibly with thin beds of clay	400
35.	Greyish blue limestone	5
36.	Shaly white limestone	6
37.	Purple limestone	4
38.	Red, yellow, and blue clays	25
39.	Limestone	300

Beyond this is Cretaceous.

The total thickness of the Coleman division as far as traced is 1660 feet. The section above will give an idea of the beds. Some prospecting for coal has been done on these beds, near Coleman, but so far without success. Thin seams of coal are quite numerous in the Coleman division, but it is quite unlikely that workable beds will be found in the section which I have described; or if by chance any should be discovered, it would be most probably a very local deposit, likely at any moment to disappear. Most of the period during which the Coleman beds were being laid down was a time when muddy water prevailed over the area. In some places the presence of a shore line is plainly shown. All the limestone, with the exception of some

beds near the base, contain great quantities of argillaceous matter, and if coal were present it would very likely share the same fate and contain so much ash that it would be more a carbonaceous shale than a coal. This is what is noticed in some of the many thin coal seams of the Coleman beds.

ECONOMICS.

COAL.—In considering the question of the amount and value of the coal in the Central Texas area, as based upon the foregoing geological facts, the best that can be done is to make a statement of the probabilities. To test the truth of my inferences and the value of my judgment the drill or the spade must be used. The amount of prospecting that has been done in the Carboniferous area is far too scant to admit of final and accurate statements concerning the economics of the coal; yet I have no doubt that further exploration will prove the truth of my general statements, and it is with confidence that I make them.

The lowest coal seams that have been noticed are those in the Sub-Carboniferous at San Saba and Brady. They are only a few inches in thickness, and are the best that can be expected from this region. In the Carboniferous proper the amount of barren territory is astonishingly large. The total thickness of the true Carboniferous along my cross-section, calculated on a basis of a regular dip of 100 feet per mile, is nearly 8000 feet, and in all this area there are but two series of beds which promise coal, and only one that has so far been proved to contain workable coal. The total thickness of these two coal bearing series is but 450 feet, or only one-eighteenth of the entire thickness of the Carboniferous.

In the entire cross-section there are not more than five feet of coal, or one-sixteen-hundredths of the entire formation. Two-thirds of the beds are absolutely barren. The Richland Sandstone beds are barren; the Brownwood Beds contain no coal; and the Coleman Beds, although having numerous thin seams of carbonaceous shale and laminæ of coal, probably contain no beds of workable coal. Traced to the north beyond the area which I have described, these beds may change in character in such a manner as to become coal bearing. Certain indications seem to point to this conclusion.

Of the Milburn series little that is definite can be said. No regular prospecting has been done. In many wells coal has been found, but nowhere in workable quantities. The beds in this series are certainly suggestive of coal, but south of the Colorado, in the vicinity of Milburn, there is probably no workable coal. It is reported to be two feet thick in a well just west of Milburn, and to have a vertical dip; but if such is the case the coal is locally out of place. If any workable coal exists in the Milburn series southwest of

where it is buried beneath the Cretaceous, it will in all probability be found in the northeast corner of the county south of Brownwood; but there is no certainty that it will be found even here in workable beds.

The Waldrip coal series is the main coal-bearing band of the Carboniferous. Its approximate boundaries have already been given above. From Waldrip to the Silver Moon mine, on the Jim Ned Creek, near Brown County line, the band of coal-bearing strata is continuous, and everywhere along this line where prospecting has been done, coal in workable thickness has been found, except in one or two instances, where its absence might readily be accounted for by some very local cause. Some of the places where coal has been found in this belt are, at Waldrip; near the mouth of Bull Creek; Dunson and Kingsbury's pasture, on Home Creek; Homes' pasture, near the Gulf, Colorado and Santa Fe Railroad, four miles east of Santa Anna; several places on Mud Creek, on Mr. W. M. Terrel's place, and elsewhere; and at the Silver Moon mine, on Jim Ned Creek. This bed also extends to the Pecan Bayou, and farther, but I have not traced it beyond the Jim Ned. More than twenty-five prospecting holes have been sunk in this belt, and almost everywhere a seam of coal varying from 18 to 30 inches has been found, with an average thickness of two feet. It is impossible to say whether these various prospecting holes have struck one and the same coal seam or not, but there is no reason to suspect that this not the case. At all points the coal seam occupies the same position relative to the permanent beds above and below. Local variations occur in the distribution of some of the beds, as might be expected. The coal itself undoubtedly varies much in thickness and composition, as it also does in exact position; but there is every reason to suspect that there is a continuous bed of coal extending at least from Waldrip to the Jim Ned. This bed may disappear entirely in isolated patches, or it may in places be replaced by carbonaceous shale. There may be thin beds of coal above and below, but nothing has been found to prove that there is any better bed than this one that has already been found in so many places.

The linear extent of the outcrop, as far as traced, can not be less than forty miles northeast and southwest. Almost uniformly within a mile, and generally within a half mile west of the coal outcrop, there is a bluff of from thirty to seventy feet in height, capped by limestone and sandstone, the lowest strata of the Coleman Beds. From the base of this bluff to a variable distance northwest, generally not more than three miles, there is probably coal within four hundred feet of the surface. Where the natural elevation of the country to the northwest is rapid, as is often the case, the belt in which coal would probably be found in a 400-foot boring is frequently narrowed down to two miles. The dip being very gentle, the coal at any point may

easily be worked far back along the dip. Assuming the average thickness of the coal to be 12 inches (decidedly an underestimate), in order to allow for places where coal may be locally absent or for some cause unworkable, and taking the linear extent of the belt to be 40 miles, and an average width of two miles, there would be over 90,000,000 tons of coal—enough to supply Texas for many years.

As to the good quality of the coal there can be no doubt, nor can there be any doubt as to the possibility of working it. Generally there is a solid roof, and beneath the coal is almost invariably an easily worked bed of fire clay, which can be removed at slight cost, which may in time be more than repaid by utilization in brick manufacture. The gentle dip is also favorable to extensive coal mining, and there is practically no danger of faults. The country has been but slightly disturbed since the coal was formed. One chief trouble which has previously prevented any development of this coal has been the absence of a market. The Finks mine, at Waldrip, is nearly 25 miles from the railway, and is separated from it by the Colorado River, which, with other bad places in the road, effectually prevents the profitable marketing of coal at the railway. This mine, after taking out one hundred tons, or thereabouts, suspended operations, not from lack of coal but absence of market. The only other place where coal has been mined in the Waldrip beds is at the Silver Moon mine, just opened. One or two tons are taken out per day, and hauled either to Santa Anna or Coleman, each of which is more than ten miles distant. There is undoubtedly coal nearer the railroad than this, but it has never been developed.

The question of quality is a serious one to be considered. For domestic purposes and for use on the railroad this coal is undoubtedly well suited; but in order to develop an immense deposit of coal some other market must be found.

At present there are no manufactories which could be relied upon to use any quantity of coal, and we all naturally look to the possible future of this coal in connection with the development of the valuable iron deposits of Llano and adjacent counties. Of the value of much of this coal in iron working I have grave doubts. The question of the quantity of sulphur contained must be carefully considered. Most of the analyses show good coking qualities, not a large percentage of ash, but considerable sulphur. (See analyses). The coal of the Silver Moon mine, which I have visited, can not be used in iron smelting unless its quality greatly improves. Sulphur in the form of iron pyrites is abundant in such quantities as to be plainly noticeable on all the pieces. A careful search in the coal cars at Santa Anna, and again on the dumps of the mine, failed to find any good sized pieces of coal without streaks of iron pyrites. When burned a strong sulphurous odor is emitted. It is

possible that the quality will improve when developed deeper. The iron pyrites appear in the seams in the coal, and may be the result of a combination of the sulphur so abundant in the alum bearing clays with iron deposited from percolating water.

Of the Waldrip coal I am not so certain. Owing to the condition of the mine, I was unable to go into it. Some of the people interested in its development have told me that there is very little sulphur, but I fear they underestimate the matter. At Brady, where I saw some of the coal, iron pyrites showed plainly in most of the pieces. The quantity of sulphur in the coal at these two points is too great to admit of its use in the best iron work, and I fear that most of the coal will have the same fault. I will say, however, that in coking fully one-half of the sulphur is driven off; and furthermore, that the Arkansas and Indian Territory coals are used in iron work, although they carry a considerable quantity of sulphur. I give below a table of analyses of coals from different parts of the Waldrip beds:

Number.	Locality.	Water.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Remarks.
1	Waldrip...........	8.250	38.275	47.275	6.200	3.250	Made from large quantity.
2	Waldrip...........	4.550	38.505	44.800	12.140	7.960	Made from one small piece.
3	Bull Creek and Coleman County.	4.050	40.400	46.750	8.800	2.870	
4	Bull Creek...	10.405	35.940	49.460	4.195	1.535	Made from large quantity.
5	Silver Moon Mine..	6.900	36.000	41.100	16.000	4.560	Made from 15 pounds powdered.

IRON.—In some of the beds both above and below the Waldrip series there is a great quantity of iron ore in the form of nodular hematitic ironstone in the clay. This iron appears to be very rich. The analysis is as follows:

Silica	4.37
Ferric oxide	89.73
Alumina	5.47
Sulphur	0.10
Lime	Trace.
Phosphosus	Trace.
	99.67
Metallic iron	62.81

Analysis by L. Magnenat.

In places this iron may be in sufficient quantities to pay for working in connection with the coal, provided the coal is found to be suitable for iron making. On Bull Creek this iron is very abundant; and near Home Creek, about five miles west of Trickham, there is a bed containing such quantities of this ore that the surface over several acres is strewn with the nodules. There are many tons on a few acres of the surface at this point.

MANGANESE.—Near Waldrip, about one and one-half miles northeast of town, there is a small deposit of manganese outcropping. It is apparently not in any considerable quantity at this point, though careful prospecting may develop better deposits.

OIL, GAS, AND SALT WATER.—Water barely saline has been found at various places in the upper beds of the Richland Sandstone series. Also near Milburn, a sipe of oil was obtained in the sandstone. The Brownwood Beds, however, seem to be the most saliferous, as well as oil-bearing. At Waldrip a strong flow of salt water has been found by boring through the Waldrip Beds into the upper strata of the Brownwood Beds. East of Waldrip salt water is also found. At Trickham and at Brownwood salt water has also been found in borings. In either of these cases the water is sufficiently briny for the manufacture of salt.

In connection with the salt water at Trickham and Brownwood both oil and gas have been found, but at neither place in sufficient quantity nor under sufficient head to be of economic value. The oil at both places is said to be a good quality of lubricating oil. Neither the Brownwood nor Trickham wells are at sufficient depth to fully test the value and quantity of the oil. To make this test wells should be drilled several miles to the northwest, and to a much greater depth than has been reached in either of these borings. After the experience in the eastern oil wells it is plainly not safe to make definite statements concerning the presence of oil, but I shall be quite surprised if oil in paying quantities is found in any part of the Carboniferous, unless up the Colorado, near the mouth of the Concho River, where there is a black bituminous shale, which in a fire can be made to burn without loss of bulk. The Sub-Carboniferous is a much more promising field for oil than the Carboniferous.

GEOLOGY

OF

TRANS-PECOS TEXAS.

PRELIMINARY STATEMENT.

BY

W. von STREERUWITZ.

GEOLOGY

OF

TRANS-PECOS TEXAS.

PRELIMINARY STATEMENT.*

W. VON STREERUWITZ.

As has been mentioned, the mountains and hills of Trans-Pecos Texas rise generally (seemingly, at least) in isolated ridges and groups from broad flats, abruptly in most cases, and either without foothills or surrounded only by those of limited extent and height. This is particularly the case with the eruptive mountains.

But even a superficial examination shows that in spite of the great variety in rock material there exists an essential connection between all of the eruptive mountain ranges and groups, and that the flats and basins between these ranges and groups, however extensive they may be, are in fact deep valleys, having depths of even 1000 feet and more (as has been proved by borings), and filled in with the debris not only of eruptive material, but also with that of Carbonic, Cretaceous, and possibly intermediate strata. This is often covered in turn with Quaternary detritus, which is in some cases more than 100 feet thick.

In the Quitman Mountains, or at least in their northern part, we have to deal with eruptive rocks only; with granites of at least two ages, and with porphyries, the latter evidently younger than the granites.

The Sierra Blanca group of mountains rises north of the first ridge of the Quitmans, and is separated from them by a valley two miles in width, which slopes gently from the mountains on either side, and west towards the river. The group consists of four isolated, moderately flattened cone-shaped mountains, the highest of which, the Sierra Blanca Peak, has a height of nearly 7200 feet above the sea level, or 2000 feet above the surrounding flat. Up to the present time no granites similar to those of the Quitman range have been detected in the Sierra Blanca group, and outcrops of dioritic

* As this is merely a preliminary statement of some few facts observed while engaged in preparatory work in the region, no reference has been made to existing literature on the subject. This will be done in a following report.

rocks exist which have not been observed in the Quitman Mountains, so far as they have been examined. Porphyritic rocks are found, however, resembling those of the Quitmans. The surface rock of the Sierra Blanca Mountains consists of a quartzitic material in sharp, angular fragments, varying in size from 6 inches to more than 6 feet, evidently a metamorphic or semi-fused sandstone, with occasionally a thin layer of crystals of hornblende. These quartzites, which are broken nearly at right angles to the plane of the original stratification, are devoid of petrifactions or impressions of organic matter. They evidently cover the slopes and summits to a considerable depth, coinçiding in their present inclination with the mountain slopes. The isolation, character, and the peculiar shape of the Sierra Blanca Mountains seem to point to laccolitic intrusions as their origin.

The four mountain cones of this group are decidedly newer than the Lower Cretaceous rocks surrounding them. The dip of the Lower Cretaceous hills in the vicinity of the Sierra Blanca Mountains is the same as that of the quartzite forming the slopes of these mountains, and the saddle of Lower Cretaceous limestone, with excellently preserved specimens of fossils, lying between two of the mountains, and stratified horizontally, seems to indicate that the upheaval of all the mountains of this group took place simultaneously and probably gradually after its deposition.

From observations made up to this time no connection can be found between the intrusive material of the Sierra Blanca cones and the eruptive rocks of the nearest or northwestern ridge of the Quitman Mountains, and it will require careful study and comparison with the Quitman Mountains, and the distant ranges and groups to the northward, to justify final conclusions.

The foothills east and south are Lower Cretaceous, with numerous and extensive porphyritic intrusions. To the west there are more recent (Quaternary?) beds, sloping gently towards the river and intersected by numerous ravines and dry watercourses. The Sierra Blanca Mountains, with their fragment-covered surface, and the foothills west of them show fewer distinct ore outcrops, and are lacking in the tempting indications of ore deposits and veins found in the Quitmans and their foothills. I regard this plainly visible presence of ore in the Quitman Mountains, and the absence of such distinct indications in the Sierra Blanca group, as additional evidence that they belong to separate upheavals, independent of each other, and also of the laccolitic character of the Sierra Blanca group.

The Quitman Mountains, which have a general northwest trend, comprise two separate parallel ridges, the northern of which is much the shortest. The northern ridge is a granitic upheaval with porphyritic intrusions, having in one place a small saddle of Cretaceous material overlying the granites. The northwestern part of the second ridge is of a similar composition to

HUECO MOUNTAINS—FROM THE QUITMAN VALLEY.

about one mile east of the Bonanza mine. There the character of the rocks changes from granite and feldspar porphyries into porphyries of augitic character, and even to basaltic rocks. Intercalations and intrusions of greenstone porphyries become more frequent, and leads with garnets (grossularite) intermixed or in contact with sideritic iron crystals and quartz are of frequent occurrence.

Both of these ridges, as far as they have been examined, are crossed by numerous vein outcrops and indications of ore, and wherever prospecting holes have been sunk there are promising indications, and even distinct veins of lead and copper-carrying silver, most of them having at least traces of gold. Occasionally also tin is present. In the deeper strata these ores are associated with zinc, which sometimes amounts to 30 per cent of the whole; and even pure argentiferous zinc ores are found. In nearly all prospects on the northeast slopes uranium is found in connection with the ore.

The prospects on the north are mostly on contacts between granites and porphyries; towards the river, on the southwest slope, on contacts between porphyries or granites and crystalline limestone. Similar contact veins between porphyry and limestone exist in the Cretaceous hills west of Sierra Blanca Station, which in all probability will yield good results when prospected to greater depth, and may change to true fissures if granite or porphyry are reached.

The outcrops of the Quitman Mountains are generally composed of iron silicates, with probably some carbonate and oxide of iron, usually containing a little silver; a few feet below the surface copperstain begins; deeper down the quantity of copper increases, and traces of lead appear with the copper. This becomes stronger the lower the shaft is sunk, and shows zinc and bismuth with the lead in greater depths. By using the pan, colors of gold are frequently found in the gravel and sand; assays of quartz and ferruginous material in many cases show at least traces of gold, particularly if such material is taken from the vicinity of the greenstone porphyries. A small piece of quartz found near Finlay assayed 11 ounces of gold to the ton. This and the general character of the rocks establish the presence of gold in the Quitman Mountains, and probably in the Carrizo and other ranges, particularly where the quartz runs with the greenstone porphyry, talcose schists, and garnets.

The Carrizo Mountains are composed principally of crystalline schistose rocks, and although these disappear underneath the Carboniferous strata of the Diablo foothills, the Carboniferous cliffs rest directly on micaceous and talcose crystalline schists with numerous large veins of quartz.

The dip of the rocks of the Carrizo Mountains and of the schists which underlie the Carboniferous cliffs is southwest towards the Eagle Mountains.

North of the Carboniferous cliffs, which lie directly west of the Eagle Flat Station on the Texas Pacific Railroad, there rises a range of hills composed entirely of fragments of eruptive and metamorphic rocks and of the Carboniferous limestones, embedded in a very hard areno-calcareous matrix, which is more or less ferruginous.

The same great breccia forms two hills about one mile from the southeast slope of the Sierra Blanca Peak, twenty miles west of Eagle Flat, and similar hills are found extending eastward to the pass leading from Carrizo Station to the Hazel mine.

These conglomerate hills, although rising as high as 600 feet above the surrounding valleys, do not seem to have been caused by any disturbance in the Carboniferous strata against which they lie in closest proximity, and their origin is as yet unexplained.

About a mile nearly due west of the last Carboniferous cliffs, which mark the south line of the Sierra Diabolo, there is a mass of basalt which has cut through the strongly metamorphosed Carboniferous limestone, and it would seem that the basalt also extended under and was the builder of the rounded hills which lie between its outcrop and the cliffs. It is hard to imagine any other cause for the entire dissimilarity which exists between these hills and the cliffs.

Greenstone and serpentine dikes are of frequent occurrence in the foothills of the Sierra Diabolo, but they disappear entirely in the southern edge of the mountains. The cliffs, composed in their upper part of strata of the Upper Carboniferous epoch, as determined by the fossils found in them, rest on a red and brown sandstone, which becomes coarser in the upper layers and changes into an amygdaloidal conglomerate embedded within a red sandy matrix. The same red sandstone, from which the limestone and the upper coarse layers have been eroded, extends north from Carrizo Station toward the Hazel mine at the southeast termination of the Carboniferous cliffs of the Sierra Diabolo. It continues through the Carrizo Pass toward the large flat north of the Van Horn Station, the soil of which is composed mostly of the detritus of the red sandstone. It also extends along the eastern side of the Sierra Diabolo Mountains; and on this side the sandstone, as well as some limestone strata which here covers the sandstone in small patches, is penetrated by numerous spar leads and copper outcrops.

The Carboniferous cliffs of the Sierra Diabolo are capped by elevations rising several hundred feet above the cliffs, and intercalations of eruptive rocks as well as intrusions will probably be found in the northern part of this mountain range, which seems to extend north to the Cornudas and south to the Chinati Mountains, or even farther and into Mexico.

If this supposition should be confirmed by detailed examination, as can

hardly be doubted, we must come to the conclusion that in Trans-Pecos Texas we have to deal with three parallel mountain chains: The one just mentioned; one east of it, from the Guadaloupe range and its continuations in New Mexico to the Sierra St. Jago and adjacent mountain ranges, crossing over into Mexico; and one west of it, comprising the Hueco, Quitman, and Eagle mountains, with their southern continuations into Mexico.

The Franklin range, north of El Paso, has always been regarded as a continuation of the Organ Mountains of New Mexico.

These mountain chains are probably coeval, at least in their oldest upheavals, and it may be found possible to connect these with the Central Texan upheavals in Llano County also. The axial direction of the three chains is southeast northwest, and such is the trend of the valleys where later upheavals and intercalations of newer eruptive and intrusive material have made no local changes, which are, however, sometimes of great extent.

The occasional changes in the dip as observed in the vicinity of the Sierra Blanca Mountains and in the foothills of the Eagle and Diabolo ranges are local, and it will be necessary to make a thorough examination of the mountains to the north, including the Sierra Diabolo, and perhaps even the Guadaloupe Mountains, before it will be safe to express an opinion about the age of the most important upheavals and the cause of the general dip toward the river. The local changes of the dip in the Cretaceous hills are readily attributed to the disturbances of not very violent character, comparatively speaking, which accompanied the intrusion of the porphyritic materials found in them.

MINERAL RESOURCES.

None of the mountain ranges mentioned have been explored by prospectors to any great extent. True there are a number of shallow prospect holes, showing lead, copper, zinc, and uranium, carrying larger or smaller amounts of the precious metals, but only a few of these prospects reach a depth of even 50 feet. The prospectors were mostly inexperienced hands, not familiar even with the character or appearance of the ores they were after. No assays or analyses were made until noticeable quantities of galena made their appearance, and it is possible that valuable ores were frequently thrown on the dump piles, and the prospects were given up when the first ten feet did not yield evident returns of the richest ore.

In the Quitman Mountains, the Bonanza and Alice Ray mines have shipped some good ores, containing 30 per cent and over of lead, 25 to 30 per cent of zinc, with from 20 to 30 ounces of silver, and traces of gold—say of an average value of $60 to $65 per ton; but owing to the fact that neither of the

El Paso smelters is prepared to reduce the zinc, instead of receiving a fair price for it a deduction of forty cents per unit of zinc is made for roasting it out of the ores. This and the charges for reducing, amounting to $10 or $15, and $3 per ton railroad freight, reduces the ore value at the nearest smelters to about $20 to $25, which, after deducting the actual cost of mining and interest on capital invested, does not leave sufficient profit for mining enterprises on a small scale. Again, the work done, even in these two mines, is hardly anything but preparatory to mining. Shafting and drifting are only the opening of a mine, the actual paying work beginning with stooping. The Hazel mine at the foot of the Sierra Diabolo is both better developed and worked on a larger scale, and fine silver-bearing copper ores in considerable quantities were shipped last spring. From reliable information it is ascertained that about ten carloads were shipped each week for ten consecutive weeks. The present output is not as high, but is still high enough to yield a good profit. Very little prospecting has been done in the Carrizo and Sierra Diabolo Mountains, although $10,000 worth of silver-bearing copper ores were taken from one prospect, the Don Quixote and Sancho Panza, from pockets not more than twenty feet below the surface, and the immediate vicinity of these prospects shows a number of equally inviting indications and outcrops. Near this locality a well defined lead of black oxide of copper can be plainly traced on the surface for several miles, but with the exception of one shaft, about 50 feet deep, and some very shallow prospect holes, no work has been done on it.

The Sierra Diablo proper consists on its southern slope and on its eastern edge, for the first eight miles at least, of horizontal strata of the Upper Carboniferous deposits, resting on a layer some sixty to seventy feet thick of a conglomerate of amygdaloidal pebbles, cemented together by a red arenaceous silico-calcareous matrix. The pebbles get smaller in the lower strata, and change finally into fine-grained, uniform, red sandstone. In this sandstone is found the lead of the Hazel mine, a gangue thirty to thirty-five feet wide of strongly siliceous limestone, without distinct walls. The limestone of the gangue, which is ore-bearing in its whole width, contains a pay streak or pay streaks of strongly argentiferous copper ore, mostly copper glanz, of a thickness varying from a few inches to ten and twelve feet. This limestone gangue becomes more arenaceous on each side of the vein, until it assumes the character of the country rock.

The experience of over 500 years in mining teaches that ore deposits (veins and lodes) are more frequently found in mountainous regions than in level countries; that they are more frequently found in older (plutonic) than in newer, and (perhaps iron excepted) more frequently in the vicinity of eruptive than of sedimentary mountains. That the presence of iron outblows, or

THE HAZEL MINE AT THE FOOT OF SIERRA DIABLO, EL PASO COUNTY.

A CARBONIFEROUS BUTTE.

even of iron-colored streaks; the outcropping of quartz, calcareous and other spars; serpentine, talc, chlorite, garnets, and other crystalline combinations; disintegrated streaks in the country rocks; contacts of different older rocks among themselves or with newer ones; changes of vegetation, and numerous other indications, justify the expectation of the existence of ore deposits. Most if not all of these favorable conditions exist in the mountains of Trans-Pecos Texas.

In addition it is an undisputed fact that the continuations of Texan mountain ranges into Mexico and New Mexico contain excellent mineral districts. The geographical boundaries have no influence on the geological character of the mountain chains. and there is therefore no reason to doubt the ore-bearing character of the mountains in West Texas, even if the mines and the limited number of faint attempts at prospecting did not prove the presence of base and precious metals, since we can not deny and doubt the ore-bearing of the same mountains in Mexico and New Mexico.

From the examinations which have been made, the Quitman, Carrizo, and Chinati mountains must be classified as excellent mineral districts, and no justifiable reason can be brought forward why the Hueco, Guadaloupe, Sierra Diabolo, Davis, Eagle, Van Horn, Chisos, Corazones, and St. Jago mountains —in short, nearly all of the Trans-Pecos mountain ranges—should not be also classified as mineral lands, since their geological and lithological character is favorable, and numerous favorable indications of the fact that they are ore-bearing, which can not be overlooked or misunderstood, present themselves everywhere, even to the superficial observer.

Among the minerals observed in this region are:

Agate, cloudy.
Agate, banded.
Agate, moss.
Aragonite.
Alabaster.
Atacamite.
Azurite.
Argentite.
Bromyrite.
Bloodstone.
Chlorite.
Cuprite.
Chalcocite.
Chalcopyrite.
Cyanotrichite.
Cerargyrite.
Cerussite.
Calamine.
Cupro-descloizite.
Calcite.
Doleryte.
Dolomite.
Epidote.
Flint.
Feldspar.
Franklinite.
Grossularite.
Glauconite.
Gypsum, massive.
Gœthite.
Galenite.
Gold, native.
Hornblende.
Hematite.
Jasper.
Limonite.
Malachite.
Marble.
Melaconite.
Magnetite.
Marcasite.
Massicot.
Onyx.
Psilomelane.
Pyrolusite.

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Pitchblende.	*Silver*, native.	*Tourmaline.*
Pitchstone.	*Stromeyrite.*	*Talc.*
Quartz, granular, glassy, milky, smoky, amethystine, aventurine, crystal.	*Salt.*	*Tetrahedrite.*
	Sulphur.	*Wad.*
	Siderite.	*Wulfenite.*
Serpentine.	*Selenite.*	*Wolframite.*
Stilpnomelane(?).	*Sphalerite.*	

There are also combinations of copper with lead, uranium, zinc, and iron; tin with lead, etc.; nickel with iron and manganese; bismuth with copper and lead; and many other minerals now awaiting determination in the laboratory.

AGRICULTURE AND IRRIGATION.

As far as the soil of the flats between the mountain chains is concerned, its fertility can not be disputed. Being composed of the decomposed detritus of the granites, porphyries, and limestone, it does not require any analysis to show its adaptability for agricultural purposes. Mr. Harrington, Professor of Chemistry of the Agricultural and Mechanical College of Texas, was with the survey in Trans-Pecos Texas during the summer, and collected soil specimens from the Rio Grande bottom lands, towards the Pecos River, and his analyses confirm the fertility of these soils. These flats of West Texas must, however, be irrigated to secure good crops. Irrigation is not a thing unknown in America, or even in the United States, and it is not a new nor insufficiently tested scheme. Irrigation from the water of the Nile, by streams in the East Indies, by springs and streamlets in Asia Minor, by artesian wells in Algiers, is proof of the practicability and of the beneficial results of irrigation, and has been practiced in some of these countries for thousands of years. Nearer home it is a well known fact that enormous results are obtained by irrigation in Mexico, New Mexico, Colorado, and California—in countries some of which have certainly no more rainfall than the west of Texas.

During the months of September and October about 11 inches of rainfall was shown by the rain gauge in the camps of the survey in El Paso County, and the rainfall from May to September is estimated to be no less. It may have been an extraordinary wet year, but the conditions in which the grass and shrubs were found the fall before last are sufficient proof that about the same amount of rain fell during 1888.

Excepting Algiers, irrigation by artesian wells is not carried on to any extent; irrigation by rivers in most cases is confined to the river bottoms or low lands adjacent to the rivers; but wherever in hilly or mountainous regions there is considerable rainfall, causing rises in the rivers, and

at times when it does not do much good to the vegetation, irrigation by storage reservoirs may be applied, provided the surrounding country and the quality of the soil justifies the expense.

Without going outside of the United States, we find the examples of this method of irrigation in California, Colorado, New Mexico, etc., where, just as in West Texas, less on account of the want of rain in general, but more on account of the want of rain in seasons when it is required for the growth of crops, has caused the unproductiveness; and this fact formerly gave the name of desert to regions which now may be regarded as garden spots.

The average rainfall for the past ten years, as measured by the United States Signal Service Office at Fort Davis, was 19.9 inches annually, or about 46,272,000 cubic feet of water for every square mile—72,000 cubic feet, or over 540,000 gallons for every acre. This average, the signal officer says, holds good for a circle of about 50 miles, and judging from one year's observations it also applies to a considerably larger radius.

This water, however, hardly ever comes down in slow drizzling rains which can be absorbed by the soil, but in heavy showers, and the water runs off as fast as it falls, a fact well known to every observer in West Texas.

In the meantime there are many long and broad valleys where frequent narrower spots are found, at which the hills and mountain sides approach each other within a distance of a few hundred yards, sometimes even narrowing to a few hundred feet.

The walls are of solid material, granites or metamorphic sandstone or limestone, and judging from the slopes of the hills as they approach each other, the bedrock is as solid as the sides, and can not be deeply buried below the overlying sand and gravel. The material for building the dams is close at hand, and in most cases can be rolled down from the sides of the hills.

The water evaporating from such reservoirs would be of benefit to the vicinity, in the shape of dew or rain; leakage will return to the surface in springs, miles off it may be, but still near enough to benefit the arid region of Western Texas.

At present, however, neither the State nor the railroad companies will be able to dispose of alternate sections for prospective farming or grazing land; they can not even rent it out to stockraisers, because there is no water, with the exception of a few springs, which are already owned by different cattlemen and provide water for only a few thousand head of cattle where there is rich pasturage for 100,000. And this pasturage is at the undisputed disposal of the parties that own or rent a small complex of land on which the springs or water holes are located.

The expenses of building reservoirs or boring wells is too great to be undertaken when only single or even alternate sections can be secured for pur-

chase or lease. The well at Sierra Blanca is 970 feet deep, and the water has to be lifted 900 feet. In Van Horn, the four wells are nearly 700 feet deep; in Valentine, about 1200 feet; in Haskell, 2200 feet deep; at Torbert a well under construction has not even reached the rock at 1000 feet. Therefore no farmer or stockraiser can invest the amount necessary for boring such wells and keeping up steam pumps for single or even half a dozen alternate sections, as there would arise complications on account of fence, way, and water rights with the alternate sections. There must be means devised by which larger tracts can be gotten in a single block before much progress can be made. But aside from the prospective farming lands and their eventual irrigation, complications will and must arise on mineral lands if the locations have to be made and surveyed from far distant starting points, as at present from the frontier of New Mexico, or from the doubtful corners now in existence. And as the price for surveying and registering a claim is small, it may be expected that the locations will be made from the nearest, which perhaps is the least reliable, starting point.

In the location of grazing or farming land in the far west, as long as no springs or other sources of water are concerned, ten or even one hundred feet are of no consequence at present, and probably will not be of any value for the next fifty, may be for the next hundred years; but in mineral districts one hundred, or even ten, feet may represent hundreds of thousands of dollars, and the value of a mine may be at stake if a line is ten or twenty feet from the place where it was supposed to be at the time when the location was made.

Veins or lodes on or near supposed section lines between the State and railroad lands, if developed to valuable mines, will invariably lead to serious complications with the State and railroad, or between the State and railroad.

If, however, the alternate sections were blocked, and the corners of such blocks finally located, then from points inside the blocks correct claim surveys could be made, even cheaper than for $20, and innumerable lawsuits, which are unavoidable under the present system, can be prevented.

DEVELOPMENT.

While Western Texas has been regarded as perfectly valueless, and its value doubted even now, because it is not settled by farmers and stockraisers, and the fact is that it is not and will not be fit for farming and stockraising without water reservoirs and irrigation, there are in the mountains mineral districts of uncommon value. The question arises, why have these resources not been developed?

This can be answered by simply hinting to the circumstances as they ex-

isted in Western Texas up to a few years ago. In former years the want of water, added to the danger of Indians, prevented the settling of Western Texas; and even travelers hurried through parts of the country, as the Sierra de los Dolores, ("the Mountains of Misery," now Quitman and surrounding mountains), with its Puerta de los Lamentaciones ("Gate of Lamentations"), and nobody stopped long enough to examine the mountains for their mineral resources; or if perchance some one did stop, he did so at the peril of his life, as is proved by the numerous graves which are found in the mountains.

Up to ten or twelve years ago military detachments were kept at stage stations on the road to Fort Davis and El Paso to protect these stations from the Indians. Under such circumstances travelers were not inclined to lay over at the station houses, which were uninviting, and to make geological examinations of the hills and mountains, or try to ascertain their ore-bearing character.

The daring pioneers who prospected and who began the development of other mineral districts of the United States had not sufficient inducement to undergo like hardships and risk their time and life in Texas, for this State had no mining law granting to prospectors any right to discoveries they may have made. The Mexicans living along the Rio Grande were farmers; very indolent, too poor to buy arms, too timid to make exploration trips to the mountains without arms.

In 1883 the Legislature of the State passed a mining law, but its contents and ruling were not very tempting. Very few persons in Texas knew, and nobody outside the State suspected, that there was really a mining law at all. It was quite natural that no mineral resources were expected in a State which did not deem it worth while to pass sensible mining laws.

The railroads made traveling through Trans-Pecos Texas easier and dangerless. They brought mountain ranges which were hardly accessible in former times in easier reach; and in 1889 the Legislature of the State passed a new mining law. The terms, however, under which this law grants mining rights to prospectors are not as inviting as those of the mining laws in force in the mineral districts in other States of the United States or Mexico. There are very few actual prospectors who are able or willing to pay the locating and recording fees, and in addition to their work make a payment annually of $50 in cash on each claim, some of which they may not wish to patent, thus entailing a loss of both work and money. This feature of the law encourages capitalists to locate and secure mineral lands for speculation, and discourages, or it may even be said excludes, the actual prospector. This law does not prevent persons from erecting corner monuments of fictitious mineral claims wherever they think good indications might be found, which will at least serve to prevent other honest prospectors from locating on them.

There are numerous such bogus locations, which have neither been surveyed by the authorized surveyor, nor recorded in the Land Office, nor the assessment work done, nor the cash payments made on them. There is nobody in the mineral districts to watch and prevent such work, even if it were prohibited by law. The required annual payment of $50 on each claim location would certainly benefit the school or University funds if locations were made under the law; but under the circumstances very few locations will be made. Most of the alternate sections, as well as larger tracts of school and University land, in West Texas in their present condition can not be sold at a reasonable price; they can not be rented out as farming or grazing land; they therefore bring no revenue through taxation, and they are, and evidently will remain, dead capital until the mineral resources are developed in the mountains, and water found or provided for in the flats; and the present mining law should be made as favorable as is possible to secure this development. But this is not the only drawback.

The titles to some of the lands of West Texas are clouded by large Mexican or Spanish grants, covering hundreds, and some of them (as, for instance, the Ronguillo grant) thousands of square miles of the best mineral and prospective farming lands. Prospectors who are able and who are willing to submit to the terms of the mining law are afraid to risk time and money without knowing on whose land they are locating, or which party, State, railroad, or grantee, has a right to grant them the rights.

In other parts of the Trans-Pecos region, where there are no Spanish or Mexican grants clouding the titles, the prospector can, in very few cases only, be perfectly certain whether his claim is located on State on railroad land, even though the location be made by the authorized surveyor, who knows or professes to know the lines. The terms which are offered by the railroad are for the most part so exacting that in fact it is almost impossible for a prospector to accept them. Thus, instead of offering sufficient inducements to secure a greater amount of prospecting, everything is against the prospector, and helps to prevent the development of the mineral resources of the State.

The scarcity of water, also a drawback to the development of the mineral and other resources of West Texas, can be overcome by storage reservoirs, and will be partially overcome by the water found in deeper mines. The scarcity of mining timber is not severely felt, for little timbering is required in the solid material of the western mountains.

The scarcity of fuel is a drawback, the greater because it prevents the utilization of the poorer grade of ores which can not stand shipment, and also in less degree on account of its need for use under steam boilers for hoisting, pumping, and ventilating machinery. But poorer ores might be stored until the coal deposits of Texas are sufficiently explored and developed to furnish

cheap fuel, or until the unjustified prejudice against the excellent brown coal of the Tertiary is overcome sufficiently to bring it into use.

The railroads will no doubt find it to their interest to make cheaper freight rates for coal and ore to and from Trans-Pecos Texas.

The mineral resources, like those of the Quitman district, will and must attract attention, and will be appreciated and utilized as soon as a more liberal mining law makes them acceptable to prospectors, as soon as the title clouds are removed, and as soon as it is possible to determine the exact location of the claims. The advantages for mining are fully as great as the disadvantages that have been mentioned; the proximity of the railroad to most of the mountains being by no means the least. The communication from the mountains to the railroad is easy, the roads either good or capable of being made so at nominal cost. The climate is healthy, and there is not the slightest danger of Indian outbreaks or other disturbances so common in many other mining districts.

CONCLUSIONS.

The mineral deposits of Trans-Pecos Texas are proved to be extensive and of great richness:

1. By their extensive outcrops, the many assays of which show the almost universal presence of the precious metals in them.
2. By the prospecting and work already done.

The advantages offered the miners and prospectors are:

1. The ease with which the outcrops may be distinguished.
2. The proximity to railroad transportation and ease of access by wagon roads.
3. The healthy climate and freedom from fear of Indian depredations.
4. Little need of timbering for mines.

The disadvantages are:

1. The present clouded titles of certain districts.
2. The lack of definite land lines, marking exact boundaries between surveys.
3. The lack of surface water. (This can be supplied by reservoirs or can be found in the mines themselves).
4. The demand for a yearly cash payment on each claim in addition to the amount of work required.

All of these disadvantages except the third can be removed by proper legislative action, and the country opened to prospectors in earnest, and as easy terms offered as those by Mexico and other sister States. When this is done, and not sooner, may we expect to see Trans-Pecos Texas take that position among the mining countries of the world which the richness of her deposits so surely warrants.

TOPOGRAPHICAL NOTES.

In examining the topographic features of West or Trans-Pecos Texas we find a continuous rise from the Rio Grande on the west and south and from the Pecos River on the east, towards the Guadaloupe Mountains and their continuations. These form the eastern and highest mountain chain crossing this part of the State in a direction extending from southeast to northwest. This ascent is not gradual on the west, but over two other mountain ranges, the Diabolos and Huecos and their southward continuations.

Although the Chinati Mountains, the Sierra Corazones, Chisos, and St. Jago reach nearly as high above the surrounding flats and valleys—that is about 2000 feet—as the Guadaloupe, Sierra Blanca, Apache or Limpia, and Quitman mountains, their altitude above the sea level is lower by at least 1000 feet. The fall of the Rio Grande from El Paso to the Devil's River is about 2700 feet, and that of the Pecos River from Pecos City to its mouth nearly 1500 feet, thus giving a considerable fall from the New Mexico line towards the southeast.

Directly north of El Paso on the left bank of the Rio Grande, rises the Franklin range. On the east side of this range the mesa rises to a height of 250 feet above the river bottom, which here extends for a width of 3 to 4 miles between the river and the mesa. The mesa itself extends over the entire region between the Franklin and the Hueco mountains, forming a flat about 25 miles wide, and extends also into New Mexico, and is there connected by a gap between the Franklin range and the Organ Mountains with the river bottom itself some 25 miles above El Paso. This mesa extends also east of the Hueco Mountains, but removing further and further from the river and also toward the Sierra Blanca Mountains, where the pass through which the Southern Pacific and Texas Pacific railroads run reaches the altitude of 4648 feet above the sea level, a rise of 1100 feet above the river bottom at Fort Hancock in a distance of less than 25 miles. From this summit at Etholen the country descends for 9½ miles to Arispa, forming there a flat basin, the deepest part of which (4500 feet above the sea level) covers nearly 30 square miles. The sides of this basin rise gradually, averaging about 100 feet in from 6 to 8 miles. The flat is terminated on the west and southwest by the foothills of the Quitman, Sierra Blanca, and Eagle mountains, with gaps or openings to the smaller flats or valleys towards the Rio Grande; on the north by the foothills of the Sierra Diabolo; while it opens on the east into the broad flat north of Van Horn, and through Bass Canyon into the large flat between the Van Horn and Davis mountains. These flats ascend gradually toward the north above Van Horn, and to the southeast towards Valentine and Ryan stations on the Southern Pacific Rail-

road, from which point they change into a more hilly country, which, at the Paisano Pass, rises to an altitude of over 5000 feet in the lowest gap between the mountains.

The mountains through which Paisano Pass is cut continue northwest into the Limpia and Boracho mountains, which again seem to extend into and connect with the Guadaloupe range, which reach in the Guadaloupe Peak a height of 9000 feet above the sea level, while the surrounding country rises to only about 7000 feet.

Southeast we find the Cathedral Mountains, the Mount Ord range, and farther on the St. Jago Mountains, with the Rosillas, Corazones, and Chisos mountains, and across the river the Sierra Carmen, the highest point of which is said to reach an altitude of 10,000 feet above the sea level.

From this mountain chain the country descends in about 50 miles from Boracho (altitude 4450 feet above sea level) to the Pecos River. (Altitude at Pecos City 3900 feet). Southeast of Fort Davis and north of Marathon Station rises an isolated and steep granitic upheaval to an altitude of 800 feet above the surrounding flats, covering about three square miles. This granite mountain is surrounded by the stratified heights (Carboniferous) of the Comanche Mountains on the west and north, and by the strongly ferruginous quartz and quartzitic mountains of the Pena Colorado range on the east, which range extends east of the St. Jago Mountains in a southeasterly direction about 25 miles below Marathon, and can be traced over 12 miles in its northwest course alongside of the Comanche Mountains. Farther north and east the Cretaceous limestone begins, forming long-stretched hills with flat tops.

RIVERS.

The Rio Grande, from El Paso to Presidio, runs southeast between mountain chains which are nearly parallel to each other and to the more eastern mountain chains of West Texas. Below Presidio this river turns more to the east (about north 60 degrees east), following this course to the south slope of the Chisos Mountains, about 10 miles west of the 103d meridian, near the 29th degree of northern latitude; there it turns nearly at right angles to the northeast, and after traversing the canyons, follows this same course, flowing between the Sierra St. Jago on the Texas side, and the Sierra Carmen on the Mexican to a point about midway between the 103d and 102d meridians, from whence it takes an eastern course, with a slight southern deflection.

The Pecos River flows in a southeastern direction, and in its lower course cuts its way mostly through the limestone strata of West Texas. With the exception of Toyah and Howard creeks, this river has no tributaries from

West Texas that are worth mentioning, as the Delaware Creek and Rio Azul or Black River join it in New Mexico. The Rio Grande, between El Paso and its mouth, has no tributaries of any importance on its left or Texas bank. Most of the creeks laid down on the maps are mere drainage channels for rainwater, some of them occasionally with a series of stagnant water pools; but for the most part, during the greater part of the year, they are as dry as they are on the maps.

The most important of these tributaries are Glenn's Creek, east of the Eagle Mountains; Cibolo Creek, which provides the Shafter Silver Mills with water along the Chinati Mountains; Tarlinga Creek, west of the Corazones; the Tornillo Creek, between the Chisos and St. Jago Mountains; and the Maravillas Creek, with its mouth about 10 miles south of Mt. Stanley, 30 miles from the mouth of the Pecos River.

From the Mexican side the Rio Grande receives at Presidio the Rio Conchas, the water of which holds out throughout the entire year, which can not be said of the Rio Grande itself above Presidio Del Norte.

WATER.

Of all the mountain ranges of West Texas the Apache or Limpia, or as they are commonly named, the Davis Mountains, are the best timbered and well provided with springs and creeks; and wherever wells are sunk water is reached at depths varying from 30 to 40 feet. Pines of 12 and even 24 inches in diameter, different species of oak, cedar, hackberry, elm, cottonwood, etc., grow luxuriantly, but more especially on the north slope of these mountains.

A number of springs are also found in the Guadaloupe Mountains, which are the sources of the Rio Azul and the Delaware Creek. Between the Guadaloupe Mountains and the Sierra Diabolo are also a number of springs, and there are also located the famous salt lakes of West Texas.

Less favored with water are the other mountain ranges of Trans-Pecos Texas; but if we except the Quitman Mountains, the Sierra Blanca, and the southeast extension of the Hueco Mountains, isolated springs, or at least indications of water, such as so-called sipes, or moist places in the rocks, are found. In many places cottonwood and black sumach indicate moisture in the ground, and it can not be doubted that wells would yield a moderate water supply in some of the mountain ranges.

Farther off from the mountains, in the flats, water can be expected only at considerable depths.

PLANTS.

The growth of pine seems to have been confined to the Davis Mountains; but a limited timbering with scrubby cedar, live oak, and spanish oak, with small

mountain walnuts and other shrubs, are found in all the mountain ranges. The flats, where not barren sand or gravel, are mostly covered with gamma grass (*Coutelona*) of different species, and buffalo grass (*Buchloe*). Of larger plants, divers cactus species, yucca plants, greasewood, catclaw, and mesquite bushes grow and show a tendency to spread more and more in a westerly direction. In the Rio Grande bottom the tornillo takes the place of the mesquite of the higher land, and the *Agava americana*, somewhat different from the Mexican species, grows and blooms at nearly every place where the altitude reaches 5000 feet. Of some importance, also, is the *Lecheguya*, a plant belonging to the *Agava* family, used by the Mexicans for making ropes and other articles of great strength, which covers large areas along the hill-sides, and is, on account of its dense growth and formidable thorns, a very great obstacle to man and animals in crossing such areas.

A

PRELIMINARY REPORT

ON THE

GEOLOGY OF THE CENTRAL MINERAL REGION

OF TEXAS.

BY

THEO. B. COMSTOCK, F. G. S. A.

FALLS OF THE LLANO—SOUTH OF LONG MOUNTAIN.

PRELIMINARY REPORT

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INTRODUCTION.

The area included in the present review comprises a portion of what has been, not inaptly, termed the "Paleozoic Region of Central Texas." The general plan of the work of this division of the Geological Survey has been to confine attention, in most cases, to the rocks of the pre-Carboniferous age, giving heed to the more recent strata only in so far as it has seemed necessary in order to present a clear and complete geologic history of the district.

As will be apparent from a cursory examination of the accompanying geologic map, the natural boundaries of this district are the escarpments of the Carboniferous and Cretaceous systems, the latter being by far the more extensive, and in some places completely obscuring the earlier rocks. No serious attempt has been made to classify any of the divisions above the base of the Carboniferous system, although incidental notes are recorded which may perhaps prove useful to students of the later sediments. As thus limited, the "Central Mineral Region"* comprises all of the counties of Llano and Mason, and large portions of the neighboring counties of Burnet, San Saba, McCulloch, Menard, Kimble, Gillespie, and Blanco, with extensions into Lampasas and Concho counties. The area in square miles is about 3800, equivalent to more than three-fourths of the State of Connecticut, and nearly one-half of the area of New Jersey, and 500 square miles more than the combined superficies of Delaware and Rhode Island, and yet forming less than .014 of the total area of the State of Texas.

Before proceeding to the discussion of the observations made this year by the present writer, it is eminently proper to put on record here a brief history of the work done by others in the past. It is unfortunate that some of the most painstaking observations and most credible information heretofore

* The title of "Central Mineral Region" is adopted by Mr. E. T. Dumble, State Geologist, to designate this district as defined above; or, more properly, a restricted area within this field.

gleaned from this region have been practically consigned to oblivion, as in the unpublished, and probably obliterated, notes of Dr. B. F. Shumard, as well as the manuscript notes of Mr. J. W. Glenn, which are obliged to assume chronological position much later than they deserve, owing to their being heretofore buried among the archives of the State at Austin.

Diligent search has failed to discover any mention in print of the earlier rocks in Central Texas, prior to the publication of two little works in 1836,* both of which refer to the existence of "iron, lead, and mineral coal" in that region. For the reason that at the date mentioned all coal was usually regarded as of the Carboniferous period, courtesy may give these authors the credit of having first announced the occurrence of pre-Cretaceous strata within this area. But such simple statements as theirs are not to be regarded as in any degree scientifically accurate. Somewhat more definite, though still lacking in precision, is the report made in 1840 by Col. Stiff, in his Guide Book of Texas.†

This contains a chapter on Geology, in which he incidentally remarks that "bituminous coal in great quantities is known to be embedded in the romantic hills that border the upper Colorado." But the character of his conclusions and other statements in the work leave no doubt that this author had no understanding of this part of his subject, and it is not proper to give him the credit of the discovery of the general geologic era of the rocks referred to. The claim made for Mr. Kennedy,‡ by Mr. Robert T. Hill,§ rests upon somewhat more substantial grounds, for Kennedy remarks: ‖

> Advancing from the coast to the interior, the more recent beds give way to beds of slate, shale, and sandstone, which are succeeded by those of the argillaceous oxide of iron and bituminous coal; still farther to the west, the appearance of transition, slates, and limestone, with trilobite enclosed, indicates the approach to the regions of mineral wealth and vegetable sterility.

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*The History of Texas; or the Emigrant's, Farmer's, and Politician's Guide to the Character, Climate, Soil, and Productions of that Country, geographically arranged from personal observation and experience. By David B. Edward. Cincinnati, 1836.

Texas. By Mrs. Mary Austin Holley, Lexington, Ky., 1836.

(The former work is given precedence simply because its author mentions having personally seen evidences of coal in the San Saba district, whereas Mrs. Holley, without having seen it, reports the discovery in almost the identical words used by Mr. Edward.)

†The Texan Emigrant. By Col. Edward Stiff. Cincinnati, Ohio. Published by George Conclin, 1840.

‡Texas: The Rise, Progress, and Prospects of the Republic of Texas. By Wm. Kennedy, Esq. London, 1841, 2 vols., 8vo.

§Present Condition of Knowledge of the Geology of Texas. Bulletin United States Geological Survey, No. 45. Washington, 1887, pp. 14, 55. (Vol. VII, pp. 392, 433.) The writer freely acknowledges his dependence upon this paper for by far the greater portion of the facts presented here, but the references given herein have all been verified anew.

‖*Loc. cit.*, vol. I, page 115 (here quoted exactly as printed).

Other writers upon Texas, before and after Kennedy, have presumed to discuss vaguely the Geology, but they have either put forth erroneous views, or have failed to notice any difference between the rocks of the interior and the adjoining areas. Even as late as 1859, Prof. G. C. Forshey* seems to have regarded the central area as a continuation of the great Cretaceous basin, although he refers to granite and Paleozoic rocks occurring farther west among "the elevated mounds and conical hills that abound at the sources of the Colorado and the Brazos."

Most of the works already quoted contain maps of Texas, upon which the topography of the Central area is depicted upon a small scale with varying degrees of accuracy, but none of them give a very correct idea of the geography.

In 1846 Dr. Ferdinand Rœmer published the first really scientific account of the region bordering upon this district, but his observations at that date extended only to near the edge of the Cretaceous escarpment upon the south. His conclusions regarding the inner area were erroneous, because they were based upon information given by others. Omitting his faulty description of Enchanted Rock, which he had not seen, his generalization is as follows: †

> This fact, in connection with the other one that on the San Saba River silver mines have been worked formerly by the Spaniards in a plutonic rock, seem to lead to the supposition that here on the tributaries of the Colorado we arrive at the boundary where the stratified rocks of the east side of the continent come in contact with the crystalline masses of the Rocky Mountains. If this supposition is correct, it follows that the Cretaceous formation is the only one of the whole series of stratified rocks which exists in this part of Texas.

In a later paper,‡ after announcing his discovery of granite and Paleozoic rocks, he summarizes as follows:

> Surrounded by these Cretaceous deposits, there exists between the Pedernales and San Saba rivers a belt of granitic rocks and of Paleozoic strata. The latter are characterized by their fossils as Silurian strata and Carboniferous limestone; both are different in their organic character from the corresponding formations in the Mississippi valley, as might be expected considering the great distance and difference of latitude.

On nearly all of the old maps a prominent mountain range was laid down in the San Saba region. Rœmer was the first to call attention to the non-existence of such elevations "above the general level of the table land." As a result of his later field studies, which included general geologic sections across the Central area, there appeared in 1852 that great work,§ which, to-

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*Texas Almanac, 1859, p. 133.

†American Journal of Science (2d ser.), vol. II, 1846, p. 364.

‡Contributions to the Geology of Texas. By Dr. Ferdinand Rœmer. American Journal of Science (2d ser.), vol. VI, pp. 28, 29, 1848.

§Die Kreidebildungen von Texas und Ihre Organische Einschlusse. Bonn, 1852, with plates of fossils.

gether with his "Texas,"* has reared an enduring monument to this most intrepid explorer and intelligent interpreter of nature. Considering the date of his trip and the hostile character of the Indians, the quality of his work is little less than marvelous. In these two masterpieces he practically demonstrates the general geology of the region, and, with few errors, presents a geological map which has been accurate enough for most purposes heretofore. This author allows too large an area for the granite exposures, which he did not and could not attempt to differentiate from the other crystalline rocks, and he errs in placing an insulated patch of Paleozoic rocks (occupying the general position of the Mason Mountain) within the granitic area. This ridge was crossed by him, and it seems a little strange that he did not detect the Cretaceous character of the greater portion of it.† But although Dr. Rœmer's views must be modified in some instances by later discoveries, his map was never intended as more than a preliminary outline, and it is noteworthy that his statements of fact, and the conclusions drawn by him from his own observations merely, are mainly correct. He is entitled to the credit of first announcing the certain existence of Lower Silurian and Carboniferous rocks in this region, and of first reporting and describing characteristic fossils from these horizons.‡

The United States and Mexican Boundary Survey, under charge of Major Emory, covered some territory adjacent to and southward from the Central region in 1853–4. The report of one of the geologists, Arthur Schott, assistant to Dr. C. C. Parry, contains a generalization upon this tract, among others not seen by him. The quotation is given here merely to explain that recent investigations have shown it to be contrary to the facts.§

Mr. Schott refers in detail to Rœmer's observations, and then remarks:

> The geographical distribution of the rocks of which Dr. Rœmer speaks permits only the conclusion that all the marks of plutonic or volcanic formation must belong to the same system, which, traversing the upper limit of the more recent Cretaceous strata in the valley of the Rio Bravo, shows itself in the shape of the low basaltic hills, etc. * * *
>
> There is no doubt that this dyke continues its northeastern direction, accompanying as an outlayer of the higher regions of the Guadalupe and Ozark mountains, and thus probably crosses the whole of Texas, and possibly Arkansas.

This peculiarly broad generalization may, perhaps, be regarded as the first

*Texas, etc., 1849; vol. xiv., 8vo., pp. 464, map.

†This fact was discovered only in the summer of 1889 by the present writer, and it is here first announced in print.

‡Texas, etc., pp. 388, 389; 1849. Kreidebildungen, p. 7; 1852. Rœmer had also announced this discovery in less detail in 1846 in his paper, already quoted, in the American Journal of Science, vol. II, 1846, p. 364.

§Report of United States and Mexican Boundary Survey. By Wm. H. Emory, Major First Cavalry and U. S. Commissioner. Washington, 1857. Vol. I, part 2 (Geology), p. 34.

attempt to fix the age of the granites of Central Texas. But, although Rœmer has nowhere distinctly stated this, one may infer that he intended to classify them all as pre-Paleozoic, for at the date of his writing silence upon this point was nearly equivalent to such a designation.

In 1858, by act of the Legislature of Texas, the first Geological Survey was authorized and placed under the direction of Dr. Benjamin F. Shumard, as State Geologist. A field party, headed by himself, covered Burnet County in 1859, but no work was done elsewhere within the limits set for the present report. Dr. Shumard must, however, have obtained in some way a very good outline knowledge of the geology of the great Central area; for, under the date of June 12, 1859, he wrote to the corresponding secretary of the St. Louis Academy of Science an announcement of the discovery of "an extensive development of Lower Silurian rocks, equivalent to the Potsdam sandstone and Calciferous sandrock of the New York system;" referring to the possible existence of "a few feet (not exceeding 50) of Devonian rocks" between the Carboniferous and Cretaceous strata. He concludes that "the Trenton limestone, Hudson River group, all the Upper Silurian, nearly all the Devonian, and the Chemung, appear to be entirely wanting, the Carboniferous strata resting directly upon the oldest Paleozoic. But the final result must await a more careful examination of the fossils than I have as yet had time to make of them."*

In 1861 Dr. Shumard also published a paper which contains very valuable notes, including several sections in detail.† Undoubtedly a part of the field work upon which these statements were based was done in 1860, and it is very probable that unfortunate events which occurred about that time have deprived this able geologist of much credit properly due him for discoveries then made. It is a pleasing task to aid a little in doing tardy justice to one so thorough and accurate in observation and deduction. The results of the first, and almost the only reliable, stratigraphic work heretofore performed in this region appear in the fragmentary papers of B. F. Shumard. In the writings referred to,‡ after some discussion of Rœmer's paleontologic data, he remarks:

> We have no further account of the Primordial rocks of Texas until 1859, when the present writer published a notice of their discovery in Burnet County (Trans. Acad. Sci., St. Louis, vol. I, p. 673), in which their parallelism with the Potsdam sandstone and Calciferous sand group of Iowa, Wisconsin, and Minnesota, and the magnesian limestone series (in part) of Missouri, was indicated.

*This letter was published in Transactions Academy of Science, St. Louis, vol. I, No. 4, pp. 672, 673; 1860.

†The Primordial Zone of Texas, with Descriptions of New Fossils. By B. F. Shumard. American Journal of Science (second series), vol. XXXII, 1861, pp. 211–221.

‡*Loc. cit.*, p. 214.

Further explorations have shown that the Primordial rocks, with their characteristic fauna, are spread over considerable areas in the counties of Burnet, San Saba, and Llano, and that they also extend into McCulloch, Mason, and Lampasas. * * * These rocks are based upon reddish feldspathic granite, * * * and they are succeeded by even-bedded, hard, brittle, remarkably close-textured, pure limestone and alternating beds of very compact dolomite, sometimes elegantly variegated with delicate flesh-colored cloudings. This formation, some of the beds of which resemble lithographic limestone, has received the name of Burnet marble, and may possibly represent the Birdseye limestone of the New York series. The fossils heretofore discovered in it are chiefly *Orthoceras* and *Straparollus*, but the few specimens we have found are so badly preserved that they are almost useless for the purpose of identifying the age of the formation.

The details of these important contributions can not be here discussed, but they will be referred to from time time in other parts of this report. Dr. Shumard gives general credit to his assistant, Dr. W. P. Riddell, who was afterwards chemist of the Geological Survey under Mr. Buckley.

In 1866 Mr. S. B. Buckley made what he termed a "preliminary report of what was done by Dr. Francis Moore and myself in the Geological Survey of the State." Mr. Hill* has given a very clear presentation of the personal quarrels and other difficulties which interfered with the prosecution of the survey and the publication of results. Very little of any scientific value was added by Moore and Buckley to the previous knowledge of our district, although several tabulated sections of the Potsdam were given.† Buckley regarded the granites and associated schists as Azoic, but aside from this apparent guess at the relations of a sub-Potsdam group, his geologic nomenclature and all his stratigraphic and poleontologic statements are mere repetitions of Dr. Shumard's announcements, with the addition of two unimportant sections of the Potsdam from new localities.

Much of the report is based on hearsay evidence, and there is reason to believe that some of the outcrops reported are incorrect.‡

Late in 1870 the Legislature of Texas authorized a second Geological Survey, but no field work was done until November, 1873, the State Geologist, John W. Glenn, assuming charge March 31st of the same year, and resigning

* *Op. cit.*, Bulletin United States Geological Survey, No. 45, p. 33, *et seq.*

† A Preliminary Report of the Texas Geological Survey, together with Agricultural Observations, and an Outline of the Mineral Deposits of the State. By S. B. Buckley. Austin, 1866.

‡ There is in the possession of the present Geological Survey a manuscript report by Dr. Buckley to Governor Throckmorton, without date or signature, but bearing evidence that it was written about the year 1867. In this some information about the mineral resources of our district is given, but nothing of importance relating to the geology. This report was prepared at a time when neither salary nor other appropriations were available.

his position for lack of public support in March, 1874.* Had Mr. Buckley's work, before and after this date, been of such a character as to entitle it to much serious consideration, it would be improper to introduce Mr. Glenn's unpublished work in this order, for no publication of it has as yet been made. But we are fortunate in having access to the original manuscript of Glenn's report, which accidentally came to light recently among the State archives.† Mr. Glenn's survey area comprised "the country for ten miles upon both sides of the Colorado River, from the southeast corner of Burnet County to the north line of San Saba County." His report, though brief, is a modest, and, for the time, considering Indian depredations, etc., a very creditable treatise upon the geology of the field traversed; for it must be remembered that he was in the field only a few weeks. In the document referred to he writes:

The limited area worked over can best serve principally as an index for the future work, and will not authorize definite conclusions except for that area.

The principal disturbance which that section has been exposed to appears to be of the *Azoic Time*, and is characterized by the disorder and confusion of the formations of that time. The upturned, folded, and contorted condition of the rocks admits of no other conclusion.

With the appearance of the Paleozoic Time a period of tranquillity ensued, effected only by gentle upheavals and subsidences, with conformable accumulation of strata; until the Periods of the *Potsdam* sandstone, *Trenton*, and *Hudson* had passed, when there was evidently a long rest in upheaved condition lasting through the *Niagara*, *Salina*, *Lower Helderberg*, *Upper Helderberg*, *Hamilton*, *Chemung*, *Catskill*, and *Subcarboniferous Periods;* when subsidence again occurred, and the formation of the coal-bearing series began upon and conformable to the *Lower Silurian*, upon which it rests. * * *

There appeared a gradual diminution of the dip angle from the *Silurian* to where work ceased in the *Carboniferous;* from an average of 15 degrees to 20 degrees near the *Azoic* to an average of 3 degrees in upper part of San Saba County. Where the *Carboniferous* succeeds and lies conformable to the *Silurian*, the dip angle was 5 degrees.

Generally the dip direction had direct relation to the *Azoic*. If to the northeast of the *Azoic*, then northeast; if southeast, then southeast.‡ * * *

The *Azoic* consists of the red granite principally intersected by numerous dykes of quartz nearly vertical. Occasionally it is gneissoid; and, where the bisulphuret of iron exists throughout it, the disintegation after exposure is rapid.

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*These facts appear (with some account of the work done along the eastern border of the Central area in Blanco, Burnet, Llano, and San Saba counties) in a letter to Prof. Hill from Mr. Glenn, published in the Bulletin of the United States Geological Survey, No. 45, pp. 39, 40.

†A Preliminary Report on the Geology of the State of Texas. By John W. Glenn, State Geologist, 1874. Manuscript in possession of the Geological Survey of Texas, Austin, 1889.

‡It is much to be regretted that the detailed maps, sections, and field notes referred to by Mr. Glenn, which were deposited in the Survey Office, at Austin, have presumably been destroyed.

The only metals observed in this formation were the *Bisulphuret of Iron* and *Magnetite*, and these so widely diffused as to deprive them of any economic value.

West of the granite in Llano County there exists an extensive field of schists, sandstone, and limestone, which was not examined sufficiently to warrant any conclusions as to their age. Small dykes of schists were found in the gneissoid granite in Hoover's Valley, and at one place on Spring Creek, in Burnet County, there appeared a small schist formation, apparently succeeding the granite.

Was it not for the interposition of a stratum of sandstone between the granite on the west and the field of schists, etc.—which stratum agrees lithologically and is connected with the Potsdam—I would assign these schists, etc., to the *Azoic*. But I shall leave them without assignment until they shall have been thoroughly examined.

The *Potsdam* sandstone of the *Paleozoic Time* consists of a series of cherty, coarse, and fine sandstones, some of which are so friable as to scarcely hold together; others are firm, even, and well colored, and superior for building purposes.

The maximum thickness of the *Potsdam* I found to be almost 200 feet, and in that I include the beds of passage whose greatest thickness is about 20 feet.

These beds of passage will figure conspicuously in the future prosperity of Texas, as they contain a *Galena* rich in silver.

The only fossil recognized in the *Potsdam* was *Lingula*. Fragments of others were taken, but as yet have not been identified.

The succeeding limestones up to the Carboniferous are of the *Lower Silurian*—the *Upper Silurian* being evidently wanting. They are analogous to the *Trenton* and *Hudson Periods* of the New York series, though there is some lack of concordance in the fossils. Of the fossils observed characteristic of the *Trenton* and *Hudson Periods* there were *Echinoderms*, *Brachiopods*, *Cephalopods*, *Trilobites*.

To the fossiliferous strata next above the *Potsdam* sandstone succeed the lamellar crystalline marbles and massive dolomite; both of which, so far as we observed, were non fossiliferous.

On the north and about two miles south of Cherokee Creek the *Carboniferous* succeeds and is conformable to the *Silurian*; at which place the dip is about 5 degrees northeast. * * *

In the Silurian are found *Magnetite*, *Red* and *Brown Hematites* of iron, *Arsenic*, *Argentiferous Galena*—all in workable quantities. Of building materials in the same, the *Potsdam* furnishes superior sandstone of fine dark colors, while the analogue of the *Hudson Period* furnishes a beautiful limpid marble and massive dolomite. * * *

Even the *Azoic*, so barren in other economic minerals, furnishes a red granite of unexcelled beauty and durability for building purposes.

Appended to this manuscript report is one from Chas. E. Hall upon the Paleontology of the district.* He makes little attempt to describe the fossils collected, owing to lack of literature and type specimens for comparison. The following extract gives all that is of any permanent value in this brief report:

At the northern margin of Towe Valley, Llano County, and also on the western extremity of Backbone Mountain, Burnet County, we procured some specimens of *Lingula* of the lower

*Unpublished manuscript report by Chas. E. Hall, dated Austin, Feb. 25, 1874. On file in the office of the present Geological Survey, 1889.

formation, probably the same as described by Dr. Rœmer as *Lingula acutangula;* * * * also fragments of others, perhaps *L. prima* (Con.?)

Near Blufftown, about three miles north on Beaver Creek, in Burnet County, we obtained some specimens of *Trilobites*. They showed in great numbers in the limestone of this locality. Comp. Rœmer, Kreidebildungen V. Texas, 1852, p. 7; and also Owen's Report of the Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, Tab. I. A., Fig. 18.

Following Mr. Glenn's resignation, Dr. S. B. Buckley became State Geologist, by appointment, early in 1874. The same year he published his first report,* which was largely a copy of his preliminary report of 1866, with amplifications. On page 72, of this last report, under the head of "Devonian," he remarks:

In 1860, when engaged with Dr. Shumard in the survey of San Saba County, some of the limestones and shales in the eastern part of that county and the northwestern part of Burnet were referred by him to the Devonian. The Trenton [*sic.*] limestone was the formation recognized; † its chief fossils found were of the following genera: *Bellerophon*, very common, *Maclurea*, *Orthis*, *Murchisonia*, *Pleurotomaria*, and some other genera peculiar to that period. Since then I have not revisted that portion of these counties, the whole of which needs re-examination.

Referring to the Lower Silurian, Buckley, in this report of 1874, recognizes "the calciferous sandrock, magnesian limestone, and Potsdam sandstone." He gives more details of rocks and fossils, but nothing which had not already been announced by Dr. B. F. Shumard. He, however, attempts a closer classification, and is the first writer who designates any particular portion of the strata of our area by the name of Laurentian. He remarks: ‡

Beneath the Potsdam, which rests unconformably upon it, is a dark blue shale in strata, upraised at various angles, large and small; lithologically it resembles some of the old slates of Vermont and New Hampshire, and also of the mountains of North Carolina, in the granite regions of those States. No fossils have been found in these Texas shales. In the bed and banks of Honey Creek, near the base of Packsaddle Mountain, it is an argillite or roofing slate, with two cleavage directions.

About four miles west of the town of Llano, in the bed of a stream, these two cleavages are well shown in the uptilted strata, extending from bank to bank, and the slate is changed into a light grey mica slate. All the gradations of such changes can be seen in Llano County, sometimes the slate being changed into a gneissoid rock with the vertical cleavages distinctly placed, forming large slabs. Friable mica slates, containing garnets, sometimes underlie the granite.

This description to one familiar with the region must appear extremely crude, and it demonstrates clearly enough the fact its author had no adequate

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* First Annual Report of the Geological and Agricultural Survey of Texas. By S. B. Buckley, A. M., Ph. D., State Geologist. Houston, 1874.

† Upon the margin of p. 72, in a copy supposed to have been corrected by Mr. Buckley, this sentence has been changed to read "The Hamilton group was recognized; its chief fossils," etc.

‡ *Loc. cit.*, p. 76.

knowledge of what properly constitutes a geologic division. With determinations equally arbitrary, he classes all the granites as Azoic, but adds:

Most, and probably all, of the granites of the Azoic region are of a later period than the metamorphic rocks associated with them.

Mr. A. R. Roessler, who had been engaged as draughtsman upon the Shumard Survey, has published for himself and the Texas Immigration Bureau maps purporting to give the boundaries of geologic systems. These were well executed and fairly accurate for the time, but they can hardly be regarded as of much original value, geologically. As mineral maps, so far as they can be trusted, they have served a useful purpose. These were published in 1875 and later.

Buckley's second report,* written after a tour through the Central area, adds little or nothing to our knowledge of the geology, although he again generalizes rather freely upon the relations of his so-called Azoic and Laurentian rocks to his Lower Silurian, but without giving any sections or describing any fossils. He mentions the occurrence of granite, with the Cretaceous directly superimposed, in Gillespie County, but refers to it as a general mode of outcrop in that region, which is certainly not the case.

Nothing of importance bearing on the geology of this region appeared in print after 1876 until the year 1884, when Mr. C. D. Walcott, of the United States Geological Survey, made a hasty trip into one of the most complicated portions of the district, and published a brief resume of his conclusions,† with a cut showing a section of Packsaddle Mountain, as he interpreted it from a partial view of the western flank. This paper is marred by two errors, as yet uncorrected by the author.‡ This is not the place to discuss the conclusions announced, which are somewhat different from the views held by previous observers, and which are rather broad generalizations from somewhat narrow observations in this area. Mr. Walcott concludes his article by stating that

The results obtained are: additional data on the Potsdam section and fauna; the Silurian section and fauna; Carboniferous fauna; the geologic relations of what has long been known as an Archæan area, and which is now referred to the Cambrian; and the determination of the age of the granite of Burnet County.

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*Second Annual Report of the Geological and Agricultural Survey of Texas. By S. B. Buckley, A. M., Ph. D., State Geologist. Houston, 1876.

†Notes on Paleozoic Rocks of Central Texas. Amer. Jour. Sci. (3rd ser.), vol. XXVIII Dec., 1884, pp. 431–433.

‡One of these, in the section figured, is the drawing of the underlying rocks which he calls the Llano group, as if they were dipping northward, instead of southward as he reports in the text correctly. The other is the use of the word "Carboniferous" to designate the upper rocks upon the summit of Packsaddle Mountain. This may be a misprint for "Calciferous," but there is nothing in the context to show it.

His opinion upon the age of "the great masses of granite observed in western Burnet and all through Llano County," is that

They are pre-Potsdam—in part cotemporary with the deposition of the sediments of the Llano group, but more largely the result of extrusions of granite at or near the close of the erosion of the Llano group and before the deposition of the Potsdam.

In a foot note he adds:

It may be that further and more complete observations will prove all the granite to have been intrusive in the Llano group prior to its erosion, but from the evidences, as seen by the writer, it is difficult to explain its occurrence except as above.

Mr. Walcott has more recently concluded, provisionally, that the Llano series is the geologic equivalent of the Grand Canyon and Keweenawan series, all of which he is inclined to regard as of pre-Cambrian horizon.*

To this idea I believe he still adheres, for in a recent paper read before the American Geological Society† he places the Grand Canyon series as a member of the Algonkian system, lying between the Archæan group and the Cambrian system.

The next expression of opinion upon the geology of the Central region is by an author already much quoted, whose stratigraphic work in adjoining areas is admirable, but who has never penetrated this part of the district far enough to speak from actual observation, except concerning its eastern border in part. Mr. Robt. T. Hill, of the United States, Arkansas, and Texas Surveys, late Professor of Geology in the University of Texas, at Austin, has been for years a most indefatigable worker in the field of Cretaceous Geology, and incidentally he has had occasion to review the work of others in the region we are now discussing. His masterly treatment of the subject in his excellent treatise‡ is the most concise and satisfactory resume of our knowledge up to the date of its publication. Since then we have nothing in print except certain allusions by Mr. Hill himself in later papers, which contain some generalizations, which appear to be more comprehensive than are really warranted by the facts as now revealed.

In a review of Texas Cretaceous strata§ he says:

The latter (Paleozoic) are exposed along a north and south axis from the Red River to the Colorado by the removal of the overlying Cretaceous.

* Second Contribution to the Studies on the Cambrian Faunas of North America. Bulletin United States Geological Survey, No. 30. Washington, 1886, pp. 57–64.

† Study of a Line of Displacement in the Grand Canyon. By C. D. Walcott. Bulletin Geological Society of America, vol. I, p. 50.

‡ Present Condition of Knowledge of the Geology of Texas. Bulletin United States Geological Survey, No. 45, 1887, pp. 55–7, 87.

§ The Texas Section of the American Cretaceous. By Robert T. Hill. American Journal of Science, vol. XXXIV, Oct., 1887, p. 301.

Again, in discussing North American Cretaceous history,* referring to the "Paleozoic area of Central Texas," he remarks:

It is also evident that it was completely covered by sediments during the two great subsidences in Cretaceous time, etc.

In the same paper (p. 284) he repeats his assertion in the following words:

The Trinity formation * * * clearly marks the interior shore line of the oldest American Cretaceous, as well as the beginning of a great subsidence which initiated that epoch and gradually covered the whole of the Texas Paleozoic area.

The same idea is reiterated in a later paper, giving details of his observations in Burnet County. In this paper† many interesting observations are recorded, and a sketch map and section are appended. The general conclusions announced are as follows:

The absence of the Devonian is probable. I made a section at Marble Falls to conclusively settle the question, and, as final authority, sent the faunas to Prof. H. S. Williams for determination. In my opinion the alleged Devonian is identically the Carboniferous limestone of North Texas, which has here been intensely metamorphosed by igneous contact. * * * The presence of *Spirophyton*, * * * and of *Chonetes* and other forms, indicates a lower Carboniferous position for these limestones, * * * while there is a complete unconformity between them and the overlying shales, sandstones, and conglomerates of the coal measures. * * *

The Lower Cretaceous rests directly upon the metamorphosed limestones of the Carboniferous at Burnet.

Mr. Hill is, I believe, the first authority who has assigned dates to the granite outburts, other than the earliest "extrusions" referred to by Walcott. He says (*loc. cit.*, p. 291):

Perhaps the two most remarkable features of this section are the great igneous disturbances at the close of the Paleozoic and Cretaceous respectively. The one at the close of the Carboniferous is most beautifully recorded in the southwest corner of Burnet County. * * *

This great granite outcrop, from which the material was secured for the State Capitol, occupies a circular area ten miles in diameter, and is of late Carboniferous or Post-Carboniferous age.

In a foot note Hill adds:

The writer believes that Mr. Walcott was justifiable from his observations to the westward in concluding that all the granite of Burnet County was Cambrian, but the evidence here described, which I think he did not see, shows it to be of later age.

The pages of this report will, I think, demonstrate that neither Mr. Hill nor Mr. Walcott have yet seen enough of the complicated geology of the

*Events in North American Cretaceous History, illustrated in the Arkansas-Texas division of the Southwestern region of the United States. By Robert T. Hill. Amer. Jour. Science, vol. XXXVII, April, 1889, p. 283.

†A Portion of the Geological Story of the Colorado River of Texas. By Robert T. Hill. American Geologist, vol. III, 1889, pp. 287–299.

Central region to justify them in thus adjusting it. But their generalizations were undoubtedly the best that could be made without further investigation than they were able to undertake, and some of the conclusions of Mr. Hill, especially, are remarkably able, considering the limits of his field of observation. The assignment of the basal rocks at Burnet to the Carboniferous is untenable. Shumard referred them to the Calciferous epoch as early as 1859;* and the present writer has traced them continuously from the undoubted Silurian outcrops farther west and south. But the real facts could hardly fail to escape one passing rapidly across the country.

In the American Geologist for January and February, 1890, Mr. Hill has also two very valuable papers which incidentally touch upon the geologic history of the Central Paleozoic area.† He says (p. 24):

> The detailed stratigraphy and structure of these important regions are unrecorded in geologic literature. But it is evident from the few cursory examinations I have been able to give it, that it is what was once a region of much disturbance, but not so excessive as the folding of the Ouachitas or Appalachians. While the latter have remained above oceanic inundation since Carboniferous time, their Texas counterparts were buried probably beneath thousands of feet of sediments during the Lower and Upper Cretaceous subsidences. * * That they are at present exposed through the erosion of the thousands of feet of Cretaceous sediments that once covered them is evident.

The only other paper prior to 1890 that touches even remotely upon the geology of the Central area is a very brief outline given by Mr. W. E. Hidden, in connection with a description of the Barringer tract, in Llano County, from which rare minerals have recently been obtained.‡

This writer remarks that "the whole surrounding region for many miles is Archæan (with occasional cappings of limestone) and granite, in various shades of color and texture, is the common country rock." Mr. Hidden quotes Hill for this Archæan designation, but unfortunately he has not verified his reference, for there is no place in any of Mr. Hill's writings where, upon his own responsibility, he has classed this or any other portion of the Central area as Archæan, while in the paper quoted by Mr. Hidden there is no mention whatever of the name Archæan.§

*Trans. Acad. Sci., St. Louis, vol. I, No. 4, 1860, p. 672.

†Classification and Origin of the Chief Geographic Features of the Texas Region. (Map.) Robt. T. Hill. Amer. Geologist, vol. VII, pp. 9–29; II, pp. 68–80.

‡A description of several Yttria and Thoria minerals from Llano County, Texas. By W. E. Hidden and Jacob B. Mackintosh. Amer. Jour. Sci., 3rd ser., vol. XXXVIII, Dec., 1889, pp. 474-486. Mr. Hidden is alone responsible for the description of the locality (pp. 474, 475) from which the quotation is taken here, as Mr. Mackintosh never visited the spot.

§A paper by Dr. Genth, published in Amer. Jour. Sci., 3rd ser., vol. XXXVIII., Sept., 1889, pp. 198–9, describes the *gadolinite* of this locality (wrongly assigned to Burnet County), but no geologic data are reported.

SUMMARY.

Thus it will be seen that the present writer entered the field with a number of unsolved problems in hand, with a large area practically unexplored, and with not a little conflicting testimony in print regarding questions which had been for the most part locally and superficially examined; partly by inexperienced and untrustworthy investigators, but also by several well known and competent authorities, whose conclusions, if incorrect, must have been due to imperfect knowledge of the facts.

If we attempt to select the most reliable evidence, it will be found disconnected in area and so little supported by detailed stratigraphic work that only a small portion of what has been heretofore published can be depended upon as the basis of any but the most crude generalizations. The work of Rœmer, as a very general outline of the geology; the careful but unappreciated and poorly presented discoveries of Shumard; the unpublished results of Glenn, unfortunately not now accessible; the hasty examination of Walcott, as far as it goes; and the study of Hill (as it affects this region), are all that can be utilized for any scientific purposes; and very much of this material can not be made to tally with the discoveries made by myself in the detailed study of the whole region in the year 1889.

The best conclusions which can be drawn from a study of the literature alone up to date are as follows:

1. That there is a large area of granite and other crystalline rocks in the district, more or less confused by disturbances of uncertain age or ages.

(a) That Walcott believed there are no Archæan rocks among these crystallines, but

(b) That his observations in 1884 were too limited in area to make this conclusion final.

2. That a group of rocks beneath the Potsdam, and including at least a portion if not all of the crystallines which were not eruptive, have been referred to the Paleozoic group by Walcott, under the name of Llano Series.

(a) That he considers this pre-Cambrian and equivalent to a portion of the Algonkian system.

3. That Rœmer, Shumard, Walcott, and all persons whose opinions are entitled to credence, have reported Cambrian and Lower Silurian rocks over a comparatively wide area in the district.

(a) The Potsdam (Upper Cambrian) is reported by all who have worked in the field.

(b) The Calciferous division, or its equivalent, is generally recognized in the writings of competent observers.

(c) The Trenton series is believed by Mr. Glenn to be included in the higher Silurian outcrops.

4. That no rocks of Upper Silurian age have yet been reported from the area.

5. That Shumard(?)* and Glenn † have reported the occurrence of Devonian rocks in the northeastern portion of the district, but that all other authorities have believed them absent.

6. That Hill has several times asserted that the Cretaceous beds once covered the whole of the Central Paleozoic region, and that he believed that the latter are only visible now through erosion.

7. That granitic intrusions or extrusions are supposed to have occurred at different ages within the area, but that authorities differ widely in fixing the chronologic order and positions of such disturbances.

(a) The idea obtained from reading the opinions of all writers is that there were only one or two epochs of disturbance; but

(b) These epochs have been variously put at, (1) Pre-Cambrian (Walcott); (2) Paleozoic (Shumard and others); (3) Late or even Post-Carboniferous (Hill).

(c) No one has assumed that, as is really the case, more than two uplifts have occurred.

The field work of 1889 is capable of much further amplification than will be found in this report, but additional data must be obtained before it will be safe to announce conclusions which may be yet in doubt for lack of the most complete evidence. What is to be stated herein will therefore comprise only those definite results which the facts known are believed to fully warrant. It may be well to state at this point that while certain of the items quoted above have been verified by the writer's observations, as many more have been found incorrect, and a very considerable amount of new and wholly unexpected structure has been worked out.

* Upon the doubtful authority of Buckley, as already quoted.

† Manuscript (unpublished) report as State Geologist, 1874, previously noted.

STRATIGRAPHIC GEOLOGY.

The preceding pages indicate clearly the nature of the problems which lay before the writer when he first entered the field in 1889. A cursory view of the area made it apparent that nothing but a very accurate survey of the region, topographic and geologic, could enable one to unravel the intricate and confused structure, complicated as it is by faults, cross-foldings, contortions, and irregular erosion. A very little study of the region proved that any attempt to trace the course of the mineral belts, to define the outcrops, and to determine the extent and character of the resources, must be based upon such detailed and connected observations as can only be made by careful instrumental work. However important and desirable in less disturbed regions, this method of procedure is absolutely essential in our area to a proper understanding of the situation.

No fact is more strongly apparent in the structure of Central Texas than the widespread character of the geology. One can not diligently note and plot dips, strikes, and faults over this tract without becoming firmly convinced that the salient structural features are not merely local phenomena, but that without doubt the foldings, plications, faultings, and unconformities here visible are but partial relics of geologic events of considerable magnitude, affecting extensive adjacent areas. Observations reported by Messrs. Dumble and Streeruwitz in Southwest Texas tend to confirm this judgment, and the trends of the uplifts are such as harmonize well with the great continental ribs of which these may possibly be the extensions. But it is not possible at present to bridge over the gaps, and to trace the buried axes very far beyond the limits of the field in hand. Owing to inequalities of erosion in part, but much more to the complications induced by successive upheavals, and the confusion arising from intrusions and infiltrations, even the relations of one part of the district to others at a distance can only be understood by accurately plotting all the structural features upon a good topographic map. None of the maps heretofore published have been accurate enough for this purpose, and it has therefore been necessary to devote much time and labor to such work, which is even now only partially completed. For this reason it has not been possible in a single season to cover the whole area in such manner as to completely close every hiatus in the geologic history, nor has it yet been feasible to determine all the conclusions which may be eventually drawn from the observations. But some of the questions left unsettled by previous workers have been, it is believed, fully solved, while upon many points which are still doubtful the experience already had will direct how and

where to seek conclusive evidence. The discussion which follows is arranged, as is most appropriate, in the order of geologic history, beginning with the most ancient strata.

I. ARCHÆAN GROUP.

Although it is one of the most important points, economic as well as geologic, to determine whether any of the rocks of the region are of Archæan date, and although full enough evidence has probably been collected to answer the question, it is hardly possible now to present the matter fully, because there remains too much work to be done in the office in the study of rock slices, and in classifying the scattered observations and correlating them. New questions, which must be worked out in the field, have also been opened.

The writer has, however, become convinced that the basal system, and probably two systems, of strata in the district of Central Texas may be properly classed as Archæan members, provisionally placed as the homologues of the Laurentian and Ontarian systems, respectively, of other areas.*

This opinion must stand or fall, in accordance with the preponderance of the evidence, when the intimate study of the collections has been completed; but the expression of it here is based upon facts of structure which have been most carefully worked out in the field. From a stratigraphic standpoint, the position taken seems well fortified by facts which do not admit of any other interpretation. Such investigations as have been possible to date lead me to believe that microscopic study of the rocks will only confirm this judgment.

This is the first reference of these rocks to the Archæan by any one who has assumed individual responsibility for the statement. Mr. Walcott, however, is the only scientific authority who has positively denied the existence of Archæan rocks in our field. As the time he devoted to the study of the region was limited, he probably saw but little of the outcrops here included, although his published section of Packsaddle Mountain was made very near some of the exposures to be described herein.

1. BURNETAN (LAURENTIAN?) SYSTEM.

A glance at a good topographic map of Central Texas will show a decided

*It is unfortunate that Dr. J. D. Dana and Mr. Andrew C. Lawson have recently proposed the name Ontarian for two very different systems. Courtesy and the more general rules of nomenclature give the preference to the former, as the first publisher; but Mr. Lawson's application is to a recognized and increasing necessity in terminology, demanding a Canadian or geographically restricted term. Dr. Dana applies it to the Upper Silurian, for which, perhaps, a more fitting term may be found, and he does not seem to urge strenuously the adoption of Ontarian, if any equally suitable name be suggested. As used herein, therefore, the term Ontarian is a systemic designation for Post-Laurentian Archæan strata.

difference in the drainage features of the Colorado River basin in Burnet and Llano counties from what is exhibited elsewhere in that valley and in other Texas hydrographic basins. The map sheets of the United States Geological Survey published in 1887, although imperfect, are accurate enough for this purpose in this region. Referring to the Burnet and Llano sheets, a little examination will reveal certain trends in the arrangement of mountain peaks and in the courses of streams which are different from those recorded in other areas. In other words, there is an area in western Burnet County, and in eastern Llano County especially, where more of these trends can be found than in any other section, within the limits of this review at least. As we pass outwards, upon all sides from this tract the stream courses and the variations in the trends of relief forms become less numerous, until at a considerable distance only one or two such bearings can be detected as prominent topographic features. More attentive study of the maps will make apparent the fact that there is one well marked line which is almost exclusively confined to limited portions of the Colorado drainage between the watersheds north and south of the Llano River between latitude 30 degrees 40 minutes and latitude 30 degrees 50 minutes in Burnet County. This particular set of trends bears nearly north 75 degrees west,* and, if it be in itself a primary element of structure, it probably marks the course of the oldest forms of continental relief in Central Texas. There is at least a possibility that the rocks now exposed in the nucleal area are part of a general trend more nearly north-south, and therefore of more importance in the matter of continent building than the present trend of the exposure would imply. But the bearing given as partially the result of erosion is also a marked structural feature, being the real strike of a series of folds which seem to be stratigraphic, and not merely foliation planes. An element of uncertainty regarding the real original trend of these basal gneisses arises from the occurrence of a much later line of upheaval, which bears along a line within 15 degrees of this course, and which has, in places, involved the Archæan rocks as well as those of more recent eras. But, while it is probable that the later upheaval has been coerced in part into the ancient Archæan trend, owing to that being the line of least resistance, the writer has recorded a number of instances where both trends can be clearly made out in the same area. For this reason it is tentatively announced that the fundamental gneisses originally occupied a lens-shaped area striking north 75 degrees west by south 75 degrees east through the region previously defined.

The reason for suggesting a possible north-south trend to the Archæan protaxis is the persistence of salient points along such a course, a feature no

*N. 84 deg. W. magnetic, 1889. Variation 9 deg. 15 min. E. Corrected, N. 74 deg. 45 min. W.

less marked than that of the folds alluded to; and it is also true that some such structure seems necessary, as Dr. Dana has remarked, to explain the subsequent geologic history of an extended adjacent area.* The uplift at the close of the succeeding Algonkian Era affords, however, a *raison d'etre* of sufficient importance, it would seem, to account for much of this. In treating of the "Interior Continental" region, Dana divides it into three portions or basins, whose boundaries consist of continental midribs, which have been marked out very early in geologic time. As to the line running northward from near our area, he writes:

> What determined this strong boundary line or limit is not clear; possibly some underground Archæan feature.

In order to settle this important question, and to get information bearing upon the extent of the more recent mineral-bearing strata, the writer made a trip to the Wichita Mountains in the Indian Territory, the results of which will appear at the close of Part I of this report.

For the purpose of avoiding deductions not justified by present knowledge, the local name of Burnetan System is here proposed for these rocks, from the occurrence of good exposures in Burnet County. Although they correspond lithologically and in other important particulars with the Laurentian System of North America and Europe, it is not wise to attempt any close correlation with distant outcrops until some more definite principles of classification are established for the Archæan Group. There seems, however, to be abundant reason for dignifying the strata with a more comprehensive title than that of a series designation, both on account of the great unconformity succeeding this period and the wide variety of the beds included. Then, too, the possibility of epochal movements of importance lends color to theoretical divisions of serial value.

The visible portion of the Burnetan strata comprises areas of three more or less distinctive classes, viz.:

(1) The nucleal plateaus, presumably never covered by the sea since emergence in the Archæan Era.

(2) A series of irregularly concentric peaks, now bare, but perhaps once covered by the later sediments.

(3) Outlying peaks and portions of the escarpment surrounding the nucleal plateaus, now capped by remnants of Paleozoic strata. These are of very doubtful occurrence, certainly very rare.

(1.) THE NUCLEAL PLATEAU REGION.

It would require too much space to give all the evidence upon which the

*Areas of Continental Progress in North America, and the Influence of the Conditions of these Areas on the Work Carried Forward in Them. By Prof. James D. Dana, Bulletin Geological Society of America, vol. I, 1890, p. 41.

supposition of the central permanent land area is based, and it is frankly admitted that the conclusions of the writer may be hereafter proven untenable as regards this point. But the only other hypothesis which can well be advanced is that the gneisses and granites of the Burnetan System are intrusives of later date than the rock divisions here placed as their successors, and the evidence is all adverse to this, as will be shown further on. There are very serious difficulties in working out structure in a region so complicated by later dynamic results, and it may be possible that all the writer's interpretations will not stand the test of more detailed examinations; but the present judgment is in favor of the existence since Archæan time of a plateau of Burnetan strata covering a considerable area in Llano County and a portion of Burnet County. Whatever may have been the original form of the island, subsequent events—prior to the deposition of the next succeeding system—caused the whole to be folded along a line bearing north 75 degrees west, and the later depositions have in part been made about an oblong-oval tract with this course as its long diameter. There is also a large tract farther west and south in Llano County which seems to be directly connected with the area just described, and whose features do not materially differ from it; but the structure is even more intricate, owing to the predominance of the irruptive rocks. It is therefore impossible to set exact bounds to the ancient topography, and all that can be predicated is that the later shore lines were apparently restricted by a similar extension of the Burnetan highlands in that direction.

(2.) THE BARE GNEISSIC PEAKS.

A considerable number of the isolated peaks and local ranges which dot the plateau areas are undoubted intrusions of much later origin than the Burnetan gneisses, as shown by the trends in which they lie, by their crossing the earliest trend, by their parallelism with the bed-planes of later strikes, and by their composition. But there are existing local elevations, composed of rocks similar in all respects to the plateau gneisses, which by some cause have escaped excessive erosion. These now lie, for the most part, along the borders of the plateau areas; not exactly as outliers to the younger escarpment beyond, but more as a separate, though irregular, cordon representing the outer edge of the uncovered plateau areas. Of this class are probably Nigger Head Peak, and other eminences in Burnet County, the Baby Head Mountains (in part), Long Mountain, portions of the Cat Mountains, and of the King Mountains and others in Llano County.

In a few instances the present condition of these hills may be due to the denudation of a former capping of later rocks, but usually where the peaks lie well within the plateau area there is no evidence that such a covering ever existed.

A reasonable explanation of the slower erosion of these elevated remnants may be found in the fact that they are made up of harder or more durable material than the plateau gneisses; and they also occupy positions in the summits of folds, which have apparently been the escape valves for igneous intrusions of later date.

(3.) THE CROWNED PEAKS.

Most of the exposures of granitic rocks in direct contact with the Potsdam Sandstone and later strata are of different character from the Burnetan gneisses, and their trends and their relations to the overlying beds show that their eruption has been later than the deposition of the capping material. These occur along the borders of the area of the exposed Archæan rocks, and they have all been elevated very materially above the general level of the sediments with which the cappings were originally continuous. I have not observed a single case of Post-Archæan sediments resting upon such granitic knobs, without being more or less affected in dip by the underlying protrusions. Moreover, in all such cases the evidence of faulting upon one side (or more) of such remnants is very pronounced.

The rocks of the Burnetan System are largely gneisses, but they graduate upon the one hand into quartzose mica schists, and upon the other into friable sandy gneisses and fine-grained binary granites and graphic granite. There is considerable variety in color between the almost white micro-granular saccharoidal aggregations of quartz grains with few minute mica scales, and the green and black and bronzy chlorite, amphibole, and pyroxene schists. Quartz, as an ingredient of most of the rocks, and as dikes or beds coincident with the regular strike, is very prominent. Orthoclase is by far the most abundant feldspar, although albite is not uncommon in parts of the system. Crystalline labradorite occurs in a bed exposed in Hoover Valley, Burnet County, but it has not been recognized elsewhere. Felsitic rocks are prevalent in some parts of the system. An interesting porphyritic orthoclase felsite, from Long Mountain, Llano County, carries much blue opal in scattered grains of the size of morning glory seed.

A large nubmer of minerals, including new and valuable species, have been taken from this system in Burnet and Llano counties. Among them may be named *actinolite, albite, almandite, andesite, andradite, amazon-stone, asbestus, beryl, biotite, bronzite, calcite, carnat, cassiterite(?), chlorite, chloropal, cyrtolite, epidote, fassaite, fergusonite, fibrolite, fluorite, gadolinite, graphite, grossularite, gummite, hematite, hyalite, hypersthene, idocrase, ilmenite, jefferisite, keilhauite, labradorite, magnetite, marcasite, margarodite, martite, microcline, muscovite, molybdenite, molybdite, opal, orthoclase, pyrite, pyrolusite, psilomelane, pyroxene, quartz, serpentine, talc, tengerite, tourmaline*, and the new minerals *nivenite, thorogum-*

mite, and *yttrialite*, described by Hidden and Mackintosh.* A much more extended list would appear if all well marked varieties were included. The foregoing species have all been collected and determined by the writer, besides some undescribed species to be noted elsewhere in the report. Besides these, Dr. Edgar Everhart, of the University of Texas, reports the occurrence of *columbite*, *samarskite*, and *phlogopite* from Barringer Hill, but I have been unable to detect these species in the material collected for the Survey.

Pyrite, *marcasite*, and a number of iron, copper, and lead ores, as well as gold and silver, occur among the strata of the Burnetan System, but they are probably largely of more recent origin, being usually associated with infiltrated masses, in streaks, veins, or pockets. The manganese ores seem also to be of this secondary character.

It is an extremely difficult matter to differentiate the rocks of this system, and to draw sharp lines of demarkation, lithologic or structural, between the great Archæan systems, which, in a general sense, seem clearly to be represented in this area. Any attempt at a classification, however acceptable the result might be upon mere mineralogical grounds, must at present be largely deficient in geognostic support; and again, if dynamic considerations be allowed to prevail, the textural foundation is not assuredly supporting, except, possibly, in a broad and rather untechnical view.

The subsequent history of the region has been such as to commingle the various trends in a most bewildering manner, and although each periodic movement has seriously affected only a part of the area, as a rule—thus enabling one to discern fairly well the contemporary facts for each locus of disturbance—the whole preceding record has usually been badly confused, if not obliterated. Such a condition is often favorable to the special study of an established series, but it is anything but conducive to safe generalization and the correlation of disconnected outcrops. All that can now be properly announced upon this subject is comprised in the following broad statements:

1. The rocks included in the most ancient uplifts are susceptible of a rough separation into three compositional and geographic series, in which there is no well ascertained warrant of overlap or unconformity. These are:

(a) The basal gneisses and granites, with perhaps the felsite porphyry, which may have formed the floor, now folded latitudinally, upon which the later members of the series were deposited.† (*Lone Grove Series.*)

*A Description of several *Yttria* and *Thoria* Minerals from Llano County, Texas. By W. E. Hidden and J. B. Mackintosh. American Journal of Science (third series), vol. XXXVIII, p. 474.

† A very pretty theory, which is supported by some of my observations, but which can not be said to be demonstrated as yet for this district, is that "the present schistose rocks * * * were laid down upon the granitoid (Laurentian) gneisses, whatever may have been the original form of these, before the main era of folding was inaugurated." This quo-

(b) A set of hornblendic and pyroxenic schists, diorites and diabases and serpentinous rocks, whose actual relation to the other rocks are not well defined, but which seem to be nearest to the basal gneisses. In this division are included the fibrolitic and garnetiferous schists of Burnet County, as well as the steatite, actinolite, labradorite, and other basic mineral belts. But it must not be inferred that our study has yet been detailed enough to verify their continuity across all the unexposed intervals. (*Long Mountain Series.*)

(c) A comprehensive and apparently distinct collection of mica, hydromica, chlorite and talcose schists and their congeners, highly siliceous for the most part, with intercalated bands of quartzite and felsitic schists. (*Bodeville Series.*)

It is worthy of especial note that this provisional ternary grouping of the Texas Burnetan strata corresponds very closely to Mr. Lawson's classification of the Lake of the Woods Archæan rocks, although the writer did not know this fact when the foregoing arrangement was adopted. (See page 29, C. C., of the volume quoted.) It may be that the structural features can be worked out in the field in 1890. A careful perusal of Mr. Lawson's report, however, shows that we have almost as good evidence as he has adduced for making this separation positive. But the occurrence of a basic group of rocks between two acidic sets is not a reliable criterion of unconformity or of epochal changes in our district, at least without a better knowledge of the stratigraphy of the system than we have yet acquired. Even the rough provisional classification here suggested may convey more of a definite lithologic conclusion than the facts will justify; for it is certain that the general impression obtained from a review of the rocks is that the basic members are of subordinate importance. But for the purpose of carrying into the field a convenient skeleton for directing future studies, I propose to make a tentative separation of the Burnetan System into series corresponding to the three sets given above. The local names, Lone Grove, Long Mountain, and Bodeville, will, therefore, be used for the present as titles for these suppositional epochs of the Burnetan Period.

Some of the gneisses weather into fantastic forms, and the occurrence of

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tation is from page 12 of the valuable report of A. C. Lawson, on the Geology of the Lake of the Woods Region, published as Report CC, in vol. I, 1885, of the Annual Report of the Geological and Natural History Survey of Canada. Many of the features of that district are strikingly like the details of the Texas Archæan, and I have been inclined, independently, to adopt a view not unlike what is quoted above. But Mr. Lawson has obtained evidence for his tract which is much more conclusive than mine, and I do not feel justified in giving to my present views the appearance of greater weight than is due to mere personal opinion. If this theory should be found tenable, a part of what is here included in the Burnetan system must then be relegated to an epochal rank equivalent to Mr. Lawson's Keewatin series, of uncertain affinities.

pits (pot holes), knobs, and crusts is very noticeable. These irregularities are due to differences in hardness, and possibly in density—the more durable parts having somewhat of a concretionary character as developed by decay. The lamination or foliation of the gneisses, not always apparent before disintegration, tends to curve about the hard kernels.* Alterations have also taken place in many of the porphyritic and schistose rocks, some of which are very interesting. Kaolinization is very common. A fine example of this may be seen two and one-half miles south of Valley Spring, in the bed of Johnson Creek where it turns suddenly eastward into this strike. Quantities of hydrated brown and yellow encrustations, often in the form of the original gadolinite and accompanying minerals, are constantly taken from the Barringer hill, on the Colorado River, in Llano County, north of Long Mountain. These contain large proportions of cerium, thorium, yttrium and associated metals. An instructive example of the alteration of amphibole to biotite upon a large scale is exhibited in the north gap of the King Mountains, at the head of a branch of San Fernando Creek, and numerous other illustrations might be given.

2. While the structural details of the Burnetan System have been but partly elucidated, there is no doubt that:

(a) The exposed plateaus and the isolated fragments of the original islands represent in the area now exposed at least two broad elevated belts of the basal gneisses of the Lone Grove Series.

(b) One median basin and the exposed parts of two exterior troughs now contain the greatly denuded remnants of the basic and acidic Long Mountain and Bodeville Series.

(c) It is impossible as yet to state whether any unconformity exists between the probably earlier Long Mountain Series and the overlying(?) schists of the Bodeville Series.

3. A fact of the greatest moment, and one which has escaped the attention of previous observers, is the existence of a great unconformity between the rocks of the Burnetan System and those of later date.

4. As will be shown in another part of this report, there are enormous quantities of undoubtedly Post-Burnetan strata whose composition indicates clearly an origin from the degradation of the Burnetan System. From which follows a suspicion that the three rock series now under discussion were deposited conformably *inter se*, and that their folding as one system took place at the close of what may have been the Laurentian Period, at any rate after the deposition of the Bodeville Series.

5. This last conclusion is somewhat fortified, or at least it is not antago-

*This process of weathering is similar to what Mr. Lawson describes at page 24 of the report quoted in the last preceding foot note.

nized, by indications of the pseudo-igneous character of the Lone Grove and Bodeville strata, but our knowledge is too meagre to make this possibility a basis for taxonomic adjustment. It may very well be that the gneisses and their superincumbent beds have been altered from a sedimentary condition, although they seem to agree well with Mr. Lawson's section, which he does not so interpret. But he does not speak of such stratigraphic evidence as we have in our area of the continuity of the schists across the folds.

Plications and contortions of comprehensive extent are not characteristic of these strata in Central Texas, although they occur locally where their origin is readily explained by subsequent dynamic events.

From what has been presented, the writer feels warranted in making the following conclusions, namely: (1) That over a limited area of Burnet County, a large portion of Llano County, and much of Mason County, there is a system of rocks composed of three fairly defined series, apparently conformable each to each, but lying unconformably below the succeeding strata; (2) that these have once been continuous across the area of their present exposures in Central Texas; (3) that they have been enormously denuded, especially in the schistose portion; and (4) that they have been folded as one subsequent to the deposition of the whole system.

As a provisional arrangement the following taxonomy is adopted, with the proviso that the author can feel almost as well satisfied, on some accounts, with a scheme which restricts the term Laurentian to the Lone Grove strata, and places the Long Mountain and Bodeville rocks in a separate system:

Group (Era).	System (Period).	Series (Epoch).	Beds.
ARCHÆAN.	BURNETAN, *or* LAURENTIAN?	3. *Bodeville.*	Mica and Chloritic Schists (chiefly *Acidic*).
		2. *Long Mountain.*	Hornblende and Pyroxene Rocks (*Basic*).
		1. *Lone Grove.*	Gneiss, Granite, etc.

AGE OF THE IGNEOUS IRRUPTIONS.*

In the Central Mineral region intrusive igneous rocks have played an important part in complicating the structure and in determining the subsequent erosion. Aside from Buckley's announcement that most of the granites are

* In this report a series of terms is used in reference to the igneous rocks, as indicated below:

An *Irruption* is understood to imply simply an igneous outburst, and an *Irruptive* its product, without regard to the mode of action.

An *Eruption* is here understood to mean a volcanic or fissure ejection, and its product is termed an *Eruptive.*

An *Intrusion* is, for our purpose, the forcing of an igneous mass into or between the strata, and an *Intrusive* is the resulting mass.

of later date than the metamorphics,* and Walcott's equally positive statement that they are all Pre-Potsdam and largely extrusions,† we have no published opinion concerning the age of any of the igneous masses with which we are here concerned.‡ Mr. Hill's diagnosis of the Burnet County granite does not include these earliest outbursts. As Walcott considered all the Pre-Potsdam rocks Post-Archæan (Cambrian at the date of his reconnoissance, but later as Keweenawan), and he regarded as Pre-Potsdam the whole of the great masses of granite "observed in western Burnet and all through Llano County," there must have been some very strong reason for his opinion. This he gives in the paper quoted, in the following words:§

At the crossing of the Llano River, on the road from Burnet to Honey Creek Cove, fragments of the shales and sandstones of the Llano group may be seen imbedded in the granite; and on Morgan's Creek, Burnet County, the Potsdam rests directly on the granite.

It need only be said here that both Buckley and Walcott have been partly correct and partly wrong. There are granites of various ages, intrusive and perhaps extrusive; but they are not all later nor are they all earlier than the beginning of the Potsdam epoch.

It is a very significant fact that the Burnetan gneisses and schists, while they have been more or less affected by eruptions of igneous material in dikes

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An *Extrusion* is the forcing of igneous matter *through the thickness* of the strata, and the material of the cross-dike thus produced is regarded as an *Extrusive*.

Interbedded igneous masses are such as have been deposited upon one stratum, and then have themselves been covered by later sediments.

Protrusion and *Protrusive* are, respectively, nominal and adjective terms for plastic upheavals beneath strata which have not been penetrated, although often folded and broken by the movement.

As in our district it is manifestly impossible at this juncture to make these close distinctions, the first two terms are here most commonly used. It is to be understood, of course, that igneous masses which are intrusive or extrusive with respect to one set of strata may be protrusive as regards other beds in the same section.

*Quoted at page 248 of this report.

†Quoted at page 249 of this report.

‡Unfortunately, Mr. Walcott has confounded two or three well marked and unconformable systems under his name of Llano Series, a mistake which could hardly have been avoided in his rapid reconnoissance, for it has taken the writer eight months of very close study to work out this structure. In treating of the typical Llano Series, further on, it will be possible to use Walcott's name, in a restricted sense, as he intended it; but in using the quotation on page 249 of this report it is necessary to bear in mind that its author included all of our so-called Ontarian and Algonkian strata in his Llano series, or group, as he then styled it (evidently with the same intended taxonomic rank as the term series is now given by the International Geological Congress, and as adopted by the Texas and other surveys.)

§Paleozoic Rocks of Central Texas. Amer. Jour. Sci. (3rd ser.), vol. XXVIII, Dec., 1884, p. 432.

of the later strikes, are also materially contaminated with intrusions (and perhaps extrusions) of an age prior to the deposition of the next succeeding system. The fundamental gneisses and the Long Mountain basic series have now no easily recognizable traces of sedimentation, and it is possible that these rocks really represent extrusions or intrusions of one or more epochs antecedent to the deposition of the Bodeville strata. I do not feel competent just now to support by detailed evidence my own leaning towards a contrary opinion, and the more especially since such high authority as Mr. A. C Lawson has claimed a minor value in his district for some such facts as could be presented from present knowledge of our area.*

Although there are features described by him in his district which do not seem to tally with the observations made in Central Texas, there is so much of detail in his work and so little nicety of calculation in my own, that it is to the interest of science to draw conclusions warily. This much may be said, however, that nothing has yet been observed in our field which indicates anything but an inferior position for the gneisses with respect to the basic series.† Mr. Lawson's case is apparently a different one, unless it be discovered that the granites and pegmatites in the trend of the Burnetan System are really extrusions of later date, but "concomitant with the folding," as in the Keewatin Series of British America.‡

That some of the interbedded igneous rocks are intrusive does not admit of doubt; for they are compressed themselves, and in many cases the adjacent schists are materially altered along the edges of the dikes. The ponderously crystalline "squeezed" feldspar (orthoclase) and the distorted quartz crystals of the Barringer Hill in Llano County are marked examples of the former, and numerous instances might be given of the latter effect. So far as my observation goes, these dikes are not confined to one portion of the Burnetan System, but they seem to transect all three series. Such variations and local manifestations as have been noted do not appear to require more explanation

*At page 67 CC of vol. I, 1885, Annual Report of the Geological Survey of Canada, the author remarks that "the dipping of the schists in opposite directions towards each other does not necessarily imply a synclinal structure." I have based my opinion in a measure upon such a structure in Central Texas. My own impression from Lawson's report is that the two cases are dissimilar.

†In these remarks the writer must not be understood as making any serious attempt to harmonize the record in two widely separated Archæan areas, which may have had a similar history, but which have not yet been brought into true relationship and can not be properly compared except by a vast amount of investigation in the intermediate territory. But as a valid excuse for delaying conclusions, the bare possibility of such parallelism, in view of the facts, may reasonably be adduced.

‡Lawson, *loc. cit.*, p. 100 CC.

than is afforded by differences in the immediate environment, affecting in unlike manner a general cause.

These are the only safe deductions from our present knowledge of the tripartite Burnetan System. Mr. Lawson, in his territory, inclines to the theory of a Laurentian System equivalent, in effect, to our Lone Grove Series, and he thinks that he has made out a great unconformity between this and his succeeding "Keewatin Series," by which name he designates a comprehensive lithologic aggregate corresponding in composition not only with our Long Mountain and Bodeville series, but including as well the members of our succeeding Fernandan System.

Irving, on the other hand, has correlated the rock groups and unconformities of the Archæan strata of nine different areas in the Lake Superior region, and his tabulation agrees essentially with the view here taken, that, speaking only of the Archæan of Central Texas, the first pronounced unconformity yet fully recognized occurs at the summit of the Bodeville Series, which is, lithologically, the equivalent of the second (in ascending order) of the five divisions of Lawson's Keewatin Series.*

With very few unimportant exceptions, each trend of the known irruptives represents the course of one of several uplifts of well ascertained geologic date. Knowledge of this fact makes it, in many cases, comparatively easy to determine upon the ground which individual injections of granite have been contemporaneous with the folding of the Fernandan strata. Or perhaps it would be wiser to say that it is not always difficult to determine which irruptions have surely been of earlier or later age. This is especially true of the subsequent outbursts, for, if traced far enough, they will be found, as intrusives or otherwise, environed by younger strata. So much it is easy to postulate, but it is a very difficult thing to put down exact lithologic criteria by which one may distinguish at a glance the granites of the different uplifts. The writer finds that he is able to pick out from the general collection, with some degree of accuracy, certain representatives of each of the different geologic periods, of which at least six are indicated by the record. As yet, however, no principles of classification have been established upon which the relative ages of these rocks can be determined by texture alone. The general impression left after much experience in the field and office is that the intimate study of thin slices will develop a basis for such a grouping. Each successive irruption, barring the youngest, has been invaded by later outbursts which have modified locally the condition of the original mass. Examples of this kind are abundant near Lockhart Mountain. A very common effect,

*Classification of Early Cambrian and Pre-Cambrian Formations. By R. D. Irving. Seventh Annual Report United States Geological Survey (Powell), 1885–6. Washington, 1888, pp. 440, 441.

also, is the local modification of the later irruptive by contact with the earlier mass through which it has cut; but this is, of course, a less important result.

IRRUPTIVES OF THE BURNETAN SYSTEM.

A few well marked features give a distinct facies to the intrusive and extrusive dikes and mounds of this system, although our study of them does not warrant the drawing of very sharp lines of demarkation at present. Such generalizations as are defensible are given below:

1. In the dikes which follow the strikes of the folds there is in most cases the unmistakable appearance of a cooling under pressure. Marked examples of this are the "squeezed" feldspar and the distorted twinnings of quartz crystals at Barringer Hill, Llano County.

2. The preponderance of quartz in enormous dikes, and as large intrusions in coarse binary granite, and as regular interlaminations in the dense graphic granites, and even in the feldspar itself, is so characteristic that it may be used as an indicator in the search for outcrops of the Burnetan strata.

3. A class of granites, possibly including both intrusives and extrusives, but more probably restricted to deposits contemporaneous with the deposition of the environing strata, comprises fine grained binary aggregates of feldspar and quartz, rarely containing any considerable portion of mica. These partake closely of the nature of the gneisses of the fundamental acidic Lone Grove Series.

4. An important, possibly intrusive, basic set of rocks occurs in uncertain relations to the other beds. These may be eruptives of the Burnetan period, and there is not a little support to such an idea, although not enough facts are known to justify such a claim.

2. FERNANDAN (ONTARIAN?) SYSTEM.

Wherever an exposure occurs in the trend north 75 degrees west, no rocks have been involved except those already classed in the Burnetan system, but there is another set of folds which includes the same strata, with a considerable addition of superimposed beds of later origin. The name Fernandan* is proposed for this system, hitherto unrecognized in this region, on account of the prevalence of the strata in portions of the valley of San Fernando Creek in

*Mr. Walcott has already used the more applicable term "Llano" as a series name, intended to embrace all the Pre-Potsdam rocks of Central Texas. But as he has made important discoveries in this region and has reported one prominent unconformity at the base of the Potsdam, it is proper to recognize these contributions to science by the retention of the name Llano as hereinafter applied. It is believed that such terminology does not do violence to Walcott's opinions more than is clearly unavoidable in view of the present writer's later discoveries.

Llano County. These beds strike about north 36 degrees west,* a trend which is well represented upon the maps of Llano and Mason counties as the general courses of many of the streams flowing into the Llano River from the north. There is abundant evidence that the dynamic event which is recorded in this structural feature was not a mere local phase of history; for its effects are to be seen in the exposed Burnetan rocks in the dykes and master joints which traverse them, and the later systems have, in a measure, indicated continuations of the uplift by their shore lines and by the distribution of certain segregated minerals.

An exceedingly interesting item is the sparing occurrence of the folds of the Fernandan System upon the east side of the Colorado River. East of a line, approximately in the strike of the system, extending from near the head of Little Llano Creek southeastward beyond the great bend of the Colorado below the mouth of Sandy Creek, no Fernandan rocks have been observed, excepting two small outcrops of the highest beds in Hoover Valley and near Nigger Head Peak. This illy-defined border seems to have been about the course of a shore line of the Post-Burnetan sea, and the present topography is, in part, influenced by that ancient feature, although the exposures of the extreme ends of the tract now have a difference of level of more than two hundred feet. This last fact has a most important bearing upon conclusions to be given later, which are entirely new, and which investigators in neighboring fields will be disposed to accept grudgingly without every scrap of the evidence which the author has collected. The extent and outline of the coast of the sea in the Fernandan Period can not be made out, owing to the faults and igneous intrusions of later date, which have dropped outlying portions of the area. But the contact of these rocks with the Burnetan System can be fairly traced across most of the country between Lockhart and Packsaddle mountains. The character of the erosion within these limits, although much modified by more recent dynamic results, has undoubtedly been affected materially by the topography and geognosy of the Burnetan and the Fernandan periods.

The exposures of the Fernandan Beds are more extensive than the outcroppings of any of the Pre-Cambrian systems. No western shore line has been detected in Central Texas. The contacts with later strata upon the western flank of the uncovered area all indicate a much greater extent beyond the limit of our field. There is a possibility that islands of the Burnetan system, or even an extended land area of that time, may have existed in the Fernandan Sea in western Llano County and eastern Mason County. But from the greater development of the northwest trend in the mountain chains

*North 45 deg. west, *magnetic*, 1889; variation, 9 deg. 15 min. east; corrected, north 35 deg. 45 min. west.

of West Texas, as reported by Messrs. Dumble and Streeruwitz, I think we may justly conclude that we have here only the accumulations of the eastern shore area of the Fernandan Period. New evidence is thus afforded of the elevation of a continental mid-rib, such as Dr. Dana has suggested, at the close of the Burnetan (Laurentian?) Period, and before the deposition of the great system of Ontarian? strata which we are now considering. Incidentally, we also have a suggestion of a near continental land area during the Fernandan Period in the nature of the extensive detrital shallow water beds which compose a considerable part of the strata of that system. Whenever the Fernandan Beds are visible in connection with the Burnetan strata, through their own excessive erosion or by reason of the persistence of prior elevations of the earlier system, there is always abundant evidence of unconformity; and if any fractures occur, the joints of the northwest (Fernandan) trend invariably cross and cut the strike of the Burnetan rocks. A very instructive illustration of the relative ages of the two Archæan trends may be seen in an exposure of the Burnetan basal gneiss a little south of Lone Grove Postoffice, Llano County. Here, upon the left bank of Little Llano Creek, contortions in the gneiss are visible, deflecting the strike from north 75 degrees west to north 36 degrees west. Sometimes, as in the upper valley of Little Llano Creek, there are appearances of faulting, but I have not yet detected any well marked break of this kind which is certainly referable to a Pre-Cambrian period. There is a well-nigh insuperable difficulty in determining such nice points of structure in rocks which partake so much of the same texture as do the juxtaposed strata of these two systems. But occasionally a belt of the later set cuts through the older trend in such a manner as to prove at least a subsequent movement. By combining the two classes of evidence, although no one observation may of itself settle both questions, we can be certain that our postulates are strictly correct. Additional support is gained from the fact that contortions occur in the lower system only where this or later trends affect its continuity. Moreover, the composition and texture of the Fernandan Beds is to a large extent that of derivatives of the Burnetan lithologic series.

Broad belts of the Fernandan strata cross the area indicated by vertical hachures upon the progress map between the meridians 98 degrees 30 minutes and 99 degrees, and traces or isolated exposures are encountered farther west. As indicated by the successive repetitions of characteristic strata in uniform, direct and reversed order, and by the very steep dips in places, there are several parallel folds. The great amount of denudation, the restricted distribution of the succeeding rock system, the absence of Cambrian and later strata, as well as the *loci* of the subsequent dynamic events, all seem to imply that a large portion of the tract described has not been submerged

since its elevation at the close of the Fernandan Period. All the later shore lines, so far as they can be presumably traced, confirm this opinion.

There is at first view less difficulty in arranging a suitable classification of the included rocks than of those belonging to the underlying system. The chance that a part or all of the Burnetan rocks may have been eruptive is not as strong an obstacle in the case of the Fernandan Beds; for if we except the intrusive and extrusive igneous masses, and possibly some uncertain basal members, there is hardly a doubt of the aqueous origin of the greater portion of these strata. But metamorphism has introduced a new difficulty. Many of the schists, which for good structural reasons may be included in this system near its base, have such a close resemblance to some of the Burnetan rocks that nothing but a close observation of many exposures will enable one to properly separate them. A few illustrations will make this statement more clear.

SECTION A.

About three-quarters of a mile below Lone Grove, on the right bank of Little Llano Creek, where the section is badly complicated by other strikes, there is a succession like the following:

Principal dip, nearly vertical, north 54 degrees east; strike, north 36 degrees west.

1. White saccharoidal rocks with very little *muscovite*; chiefly *saccharite* (*andesite*, var.)
2. Quartz and black mica schist, underlaid by
3. Dense ferruginous hornblende? schist.
4. Granite masses, with engulfed fragments of black mica schist and other rocks.
5. Slabby, dense, mottled, biotitic gneiss, apparently overlaid, on dip of south 54 degrees west, by
6. Granular quartz rock, ferruginous, 50 feet.
7. Loosely aggregated crystalline dolomitic marble.
8. Similar to 7, less altered.
9. Similar blue-gray marble, tough.
10. Black mica schist parting of ten inches.
11. A kind of porous chalky *ferro-calcite*, apparently burned by igneous intrusions.
12. Very fine grained, ferruginated, black mica schist, with granite inclusions ($G=3.133$); 25 inches thick.
13. Altered oligoclase? granite.
14. Contorted hard gray marble.
15. Bluish and white *albite*, much broken by joints.

And so on, with felsitic and calcareous strata, badly broken by cross strikes of Post-Fernandan uplifts.

SECTION B.

Between the Little Llano, near its head, and Arrott's Branch, and farther

down the valley, a good exposure, of which a part is given below, occurs in the northwest strike. This outcrop is affected seriously by a later fault.

Dip from 50 degrees (on west) to 73 degrees (on Arrott's Branch), south 54 degrees west. Beginning above—

1. Brittle white quartz in thick bands and dikes.
2. Euritic granite, pink-brown gneissoid, intrusive in amphibolitic schists.
3. Continuation of schists, with bands of
4. Friable brown gneiss, gradually becoming tough.
5. Tough blue indurated shale, or slate, thinly fissile.
6. Chloritic schist (*prochlorite?* G=2.963).
7. Altered schist (G=2.94), chloritic?.
8. Blue marble, part coarsely crystalline *calcite;* part compact, streaked blue marble (G=2.692), part crystalline-granular dolomite.

SECTION C.

In the upper course of Johnson Creek, northwest of Valley Spring, Llano County, at a mound known as "Iron Mountain," the following incomplete section is afforded. This is not badly confused, but as in many other places a portion of it is covered by wash from the later terranes. In this instance the upper part of the section is obscured, but exposures farther to the southeast lap over in such a manner as to give the proper connection.

Beginning upon the southwest with nearly vertical strata, dipping south 54 degrees west, the rocks appearing beyond the wide area covered by detritus, are—

1. A granite or mica schist series, in part rotten and highly micaceeus, with included bands of porphyritic granite intrusions?, the whole representing apparently a horizon below Nos. 1 to 4 in Section A. These are followed below by
2. A thick deposit, in strike, of very pure *magnetite*, with *hematite* shading very gradually below into quartzose magnetic schist; in all 50 feet to 60 feet.
3. A band of binary granite (altered) carrying much *magnetite* and a green phosphatic mineral (glauconitic *apatite*), below which is
4. Fine-grained sandrock (brownish), with scattered grains of *magnetite*.

Then follows, in the anticlinal areas and beyond, upon a steep north 54 degrees east dip, a great thickness of

5. Granular, micaceous, schistose rocks, somewhat like the latest (Bodeville) series of the Burnetan System, but more friable and less crystalline, with bands of fine-grained quartzite.

Southeastward, in the continuation of this strike, which crosses the Llano River 4 miles west of Llano City, this section is in part repeated, and its extension upwards may be defined as follows, viz.:

6. *Magnetite* and congeners, similar to Nos. 1 to 4, in reverse order, overlaid by
7. Graphitic schists, followed by
8. Slates and schists, tough, more or less chloritic; overlaid by
9. Crystalline dolomitic marbles.

SECTION D.

East of the Riley Mountains, south of Honey Creek, north of Sandy Creek, and west of Packsaddle Mountain, there is a peculiar plateau in which a very good section of the Fernandan rocks may be secured, owing to a rare combination of favorable circumstances. Here the folds seem to have been less pronounced, so that the dips are comparatively slight. The intrusive masses have been less effective and the later upheavals have caused faults around the edges of the area, so as to leave the field in a fair condition for studying the events of the Fernandan Period. Moreover, the erosion here has been of a character to expose the beds well.

Below is given a general section across the strike (north 36 degrees west), in a part of this area where the dip averages from 25 degrees to 40 degrees south 54 degrees west, beginning above:

1. Blue dolomitic marbles, coarsely crystalline, with bands of tougher, mottled, dark marble.
2. Tough, shaly slates and schists of chloritic aspect, variable.
3. Blue graphitic and coal-black carbonaceous schists, more or less siliceous.
4. *Magnetite* and *hematite* (altered) series, including magnetic schists.
5. Sandy, fine-grained quartzites, shading into
6. A well developed set of granular schistose and micaceous metamorphics, exhibiting evidences of detrital origin.
7. An uncertain set of hornblendic and other semibasic schists, whose texture and structure do not indicate in all cases a positively aqueous origin.

OTHER SECTIONS.

By omitting from Sections A, B, and C such numbers as are not common to all exposures—a good proof in our region that they are intrusive or extrusive—and by combining incomplete sections and those which are isolated, it will readily be seen that section D is very comprehensive, including all the members in the sequence as exhibited elsewhere. A very large number of disjointed sections might be given, fitted together by rejecting the overlaps, and they would all confirm this as the typical section. There are many exposures in which one or other of the seven lithologic sets appears to be absent upon cursory observation, but I have always found that close examination in such cases reveals as much of this type section as local circumstances of erosion and subsequent deposition of detritus will demand as an assurance of orignal completeness.

THE GENERAL SECTION.

From the foregoing examples it will be seen that with a general similarity of lithologic composition, and with an induced general structure which has brought all the Fernandan Beds into one strike, there are, nevertheless, two

causes of local variation, which make it necessary to select particular exposures for typical comprehensive sections. These last are only to be found in their entirety, without confusion, in localities where neither the cross-trends nor the igneous intrusions have contaminated the record. The best region for such sections is in the west and north, where the latest disturbances have had least effect, and where the rocks have been least commingled with igneous material, but all causes have acted most opportunely; also in a limited area in the southeast.

There are no known epochal unconformities within this system. All that can now be safely reported as to the succession of the strata is embodied in the following generalizations:

1. The base of the Fernandan System is apparently a series of tough, hornblendic schists, possibly eruptive, but perhaps more probably detrital. They seem to be less uniform, less crystalline, more quartzose, and often more slaty than the basic Long Mountain Series of the Burnetan System. These have the appearance of rocks made from the degradation of such material as probably constituted the shore line during their deposition, namely, the mica schists and the basic rocks of the Long Mountain and Bodeville series, respectively; but they may have been largely igneous.

2. Superimposed upon the basal schists is a thick series of mica schists, so much like some members of the Bodeville Series as to require close observation to distinguish them, but almost always of a clearly discernible detrital origin, which is not to be mistaken even in hand specimens. Exceptions may occur in the vicinity of igneous intrusions.

3. There is a class of very fine-grained quartz rocks occasionally more or less contaminated with comminuted mica scales. These may have resulted from the wearing down and rearrangement, in quiet water, of the minerals of the acidic rocks of the Lone Grove and Bodeville series.

4. *Magnetite*, sometimes with *hematite*, in a bed usually about 50 feet thick, is a constant accompaniment in a definite position between set 3 and set 5.

5. Carbonaceous schists overlie the iron ore beds. These are of two well marked varieties: (1) A fine-grained, blue or gray, shaly to foliated, graphitic schist; (2) a dense, jet black, slaty, rather tough, indurated shale, having at a little distance the appearance of coal or bituminous shale. There is considerable variety in the proportion of graphite in the blue-gray beds, but the greater portion is not rich enough for economic purposes.

6. A great collection of slaty schists, largely chloritic, but not as a rule foliated, lies above the Carbonaceous rocks in most of the sections which have been observed. There may be a doubt whether the coal-black shale may not shade imperceptibly into this set from below, because there appears to be a slight discrepancy between some of the sections given in this respect.

But it is not possible now to do more than to block out roughly the lithologic series represented, and similar gradations are possibly present in other parts of the system.

7. Overlying all is an important calcareous series showing textural alteration, which implies much change since the deposition of the strata. The same is apparent all through the Fernandan System; and while it may be due in part to the intrusive rocks, that supposition is not sufficient to explain all the facts of this kind, which are usually as prominent in one locality as in another, irrespective of the distribution of the intrusives.

TAXONOMY OF THE SYSTEM.

It is not proper to offer any theory regarding the epochal mutations during the Fernandan Period. Authorities differ greatly as to the arrangement and terminology of the various Pre-Cambrian Series, and it is too early in our study to make fast boundaries which better knowledge may oblige us to retract. But a provisional classification seems essential to further progress in this complex area.* It will also serve as a tool, perhaps only temporarily, for elucidating the record. While it may be an error to place either the Ontarian or our Post-Laurentian Fernandan System in the Archæan Group, and while other imperfections will no doubt be discovered in my arrangement eventually, I have found it impossible to adopt any other without risking the assumption of too much authority or too much favoritism. The following schedule has at least the merit that it preserves the synchronic order of deposition, as far as known, upon a framework which can be finally adopted or rejected without affecting anything but the credit of an humble investigator:

Group (Era).	System (Period).	Series (Epoch).	Beds.*
ARCHÆAN.	FERNANDAN, *or* ONTARIAN?	3. *Click.*	7. Calcareous Rock.
		2. *Iron Mountain.*	6. Chloritic Slates and Shales. 5. Carbonaceous Schists. 4. Ferruginous Rocks. 3. Quartzites.
		1. *Valley Spring.*	2. Acidic Schists. 1. Basic Schists.

*The separation of the beds into series is based chiefly upon assumed similarities in the conditions of deposition, but the arrangement can not be considered very satisfactory.

*The writer will find it necessary to send assistants, with hammer and compass, to trace out and map in detail many points of structure here only indicated, and this work can hardly be accomplished without some such preliminary skeleton as is here given. It is believed, however, that all who are interested in this part of the report will have no difficulty in distinguishing between the facts themselves and the interpretations put upon them here, tentatively.

IRRUPTIVES OF THE FERNANDAN SYSTEM.

The following generalizations embody all that can be predicated with safety concerning the igneous ejections which occur as associates of the rocks of this period. Although these conclusions must be regarded more in the light of preliminary observations than as strongly intrenched deductions, they may be taken at least as indications of the direction in which future studies may be expected to lead:

1. The granites which occur in the characteristic trend of the Fernandan strata, and as ramifying intrusions, are usually different in aspect and texture from the fine-grained sandy gneissoid intrusives of the Burnetan System, although they have relations to those rather closer than to the more recent igneous intrusions.

2. There is an interesting class of white bedded granites which, when present, always seem to accompany the quartzite division of the Iron Mountain Series. These beds are probably contemporaneous with the adjacent rocks, although they may be interbedded eruptives.

3. The real intrusions of this system are, as might be expected, more commonly associated with the schists, where they are somewhat frequent as narrow dikes, and to some extent as branching feeders. But the occurrence of extrusions of somewhat greater dimensions, apparently traversing the whole section, is not improbable, although none of these are known to be of the Pre-Paleozoic age.

4. The fact that the trend of the Fernandan System has pushed aside the Burnetan trend in places where exposures of the intrusives of both systems occur, seems to imply the plasticity of the older magma as late as the close of the Fernandan period. This partly explains the evidently fluid condition of the intrusives of later date, which may account for the distribution as announced above, and for the composition as given below.

5. The filling of the dykes is chiefly a red crystalline granular binary granite, well compacted, somewhat less quartzose than the earlier outbursts. The quartz occurs both coarse-grained and as plates, but it is rarely distributed in the very regular manner characteristic of the Burnetan irruptives. The feldspar is chiefly *adularia*. In short, the general effect is that of a magma which has not been as much compressed as in the case of the prior intrusions. Mica is rarely present, and then usually in much elongated prisms, as if alteration products.

6. Quartz dikes are less frequent and much less extensive than in the previously formed system.

7. As in the lower system, there are basic rocks of one set or more which may possibly be interbedded volcanics. Some color is given to this view

from their apparently greater development in some localities than others, but the statement is by no means strongly supported by past observations.

II. EPARCHÆAN GROUP.

There is less apparent propriety in placing the next succeeding system in a different group from the Fernandan than there is in separating the former from the overlying systems by a profound distinction. Structurally speaking, the affinities of the strata above the Click series are much nearer the Archæan than the Cambrian. Lithologically, there is perhaps quite as great a divergence upon one side as the other, but the impression made upon the student in the field must certainly be more in favor of an Archaic reference. In the absence of fossils one is also left in doubt whether to regard the beds as belonging to a Pre-Paleozoic Post-Archæan group, or to consider them as an independent group above the Archæan. There seems to be no doubt that most modern geologists would rule them out of the Paleozoic.

Probably the best assignment for the present is to the Eparchæan Group of the United States geologists. Only one system has been recognized in these Pre-Cambrian rocks, for which I propose the name *Texan*, as the provisional equivalent probably of the whole of Walcott's Algonkian System.

3. THE TEXAN (ALGONKIAN?) SYSTEM.

As remarked before, Mr. Walcott first gave the county name of Llano to a set of "alternating beds of shale, sandy shales, sandstone, limestone, and schists" in the Honey Creek Valley, "that strike east and west, dipping south 15 degrees to 40 degrees." Wherever he met any of these rocks he seems to have found their general strike to be latitudinal. Such evidences to the contrary as he must have seen "across the valley of Honey Creek" in going "four miles west of Packsaddle Mountain," he has explained by stating that there "the strata of the Llano group have been more metamorphosed, plicated, and broken by intrusive dykes of granite."* The further facts that he found Cambrian sandstone resting upon granite on Morgan Creek, in Burnet County, and upon his Llano strata at Packsaddle Mountain, were accepted as conclusive evidence of the Pre-Potsdam age of the granites of the region. It would probably have been impossible to unravel the history of this complex area without wider knowledge than could be gleaned in the time at his disposal; but his choice of field was peculiarly unfortunate, because it led him into errors which might have been avoided by the examination of a limited encircling area. The district between Packsaddle Mountain and the Riley Mountains is one in which the true trend of the Texan system, includ-

*Paleozoic Rocks of Central Texas. American Journal of Science (3d ser.), vol. XXVIII, 1884, p. 431.

ing the Llano Series, is not clearly exhibited. East of Packsaddle, especially southward, outcrops are abundant. These he probably did not see. In the only two cases reported by him these rocks were involved in the strike of an uplift of much later date than the close of the Eparchæan Era. Mr. Walcott himself obtained a hint of this, but his "hurried reconnoissance" did not give him an opportunity to trace the connection between this "movement," which he says "appears to have been at the close of the Paleozoic," and the present position of the Texan Beds, where he observed them.

In our field one must have considerable knowledge of the dynamic history before he can determine how much to include in each group or system of strata, and this statement is especially applicable to the older non-fossiliferous rocks. The discovery of undoubted Texan beds unconformably beneath the Potsdam does not necessarily imply that the former are occupying the position they had before the deposition of the latter; and, as a matter of fact, there is much unmistakable evidence that the Potsdam in Packsaddle Mountain was not laid down upon the Texan Beds while they were elevated in an east-west trend.

The course of an uplift which has involved the strata of the Archæan and Eparchæan groups, and no others, is the one which will give the true Texan trend. This bears almost due north and south*, and it can be clearly made out in parts of Llano and Mason counties. A portion of Packsaddle Mountain east of Walcott's section lies in this strike. Southeast of Packsaddle Mountain, especially in the neighborhood of Sandy Mountain, and northward in the north-south course of the Llano River, there are good exposures of this trend showing some of the characteristic Texan strata, including also a portion of the underlying Fernandan System. The present eastern boundary of the outcrops may, for good stratigraphic reasons, be assumed at a line about in the general course of the Colorado River between Burnet and Llano counties. No outcrop has been discovered east of the river. Evidences of a shore line along this confine are visible, but much confused by more recent dynamic events. The relative elevations of different exposures, the excessive contortions, and other phenomena, all indicate much faulting; and there has certainly been no more difficult problem in this field than the working out of the Texan section, which is still but imperfectly accomplished. In Mason County a broad belt of this orographic system is exposed, largely in the drainage area of Comanche Creek north and south of Mason City. Some very troublesome questions concerning the stratigraphy are as yet unsolved, the search for fossils being heretofore unsuccessful and the effects of the uplift at the close of this period tending in places to mislead. There is a strong

*North 10 degrees west, *magnetic*, 1889; average declination 9 degrees 15 minutes east; *corrected*, north 0 degrees 45 minutes west.

suspicion also that a new element of stratigraphic interpretation must be used to explain some peculiar situations; but as this feeling may possibly have arisen from a misconception of the facts, it is simply suggested here as a starting point for more thorough investigation. The feature referred to is the existence of certain breaks in the Paleozoic strata which follow courses more nearly equivalent to the Texan trend than to any other. The only reasonable interpretation seems to be based upon the supposition that lines of weakness existed in the Texan strata long after the close of this period of upheaval. Further discussion of this topic is deferred to a more appropriate place under the head of the Paleozoic Group.

Two very significant conclusions have been first forced upon the writer's mind by the study of these beds, and again even more persistently by the consideration of the facies of the next succeeding system. (1) There must have been a vast amount of erosion after the folding of the Texan strata and prior to the deposition of the Cambrian sediments upon the upturned edges. (2) The material of the Cambrian must have been provided in part from the disintegration of the Texan strata.

As Walcott has found evidence of the deposition of two great series of rocks in Arizona during this probable hiatus in a part of the history of our district, it is presumable that the shore line in Central Texas was more or less variable during the interval. A little evidence has been collected which admits of this interpretation, but much has been of necessity left for future study.

The following observations will serve to fix in the mind the relations of the Texan system:

1. There are three prominent parallel belts in which the north-south trend of these strata is exposed by the denudation of later systems, as follows:

(1) Over much of the region south of Long Mountain, west of the Colorado River, and east of Packsaddle Mountain.

(2) In a tract west of the Riley Mountains, extending nearly the whole width of Llano County from north to south.

(3) Irregularly over a district about ten miles wide, bounded upon the west by a line passing near Camp San Saba, Katemcy, and Mason.

2. The outcrops of our Texan strata are almost invariably accompanied by some of the Fernandan beds, or by members very closely resembling these, often in such relations as to make it difficult to determine the boundary between the two groups upon structural grounds alone; but the rocks here included as of the Texan System are never involved in an earlier uplift than the north-south trend.

3. The Texan System has been so materially affected by erosion and by the dynamic history of later geologic periods that perhaps there is not now

existing in our area any one section from which the continuous record can be made out.

4. The conclusions here announced may require modifications after more thorough examinations, guided by the knowledge already acquired, but it is very probable that such changes as may be necessary will be rather serial than systemic in their scope. For, with all the complications induced by subsequent orographic movements, and notwithstanding the gradual approach of Cambrian conditions in the upper beds, the stratigraphic relations are plainly with the preceding group as now defined by geologists.*

Mr. Walcott in his illustrated section of Packsaddle Mountain† has failed to fully interpret the structure, because he saw only a part of one side, near where the intermingling of strikes and the occurrence of blind faults have much obscured the original Post-Texan uplift. Evidently all of his so-called Llano strata are what are here classed as Texan, and the base of his Potsdam includes a considerable portion of our earlier Cambrian systems, as will be explained elsewhere. (See Hickory Series beyond). He certainly did not detect the south dip of 14 degrees in the Cambrian sandstones at the northwest point of the mountains, where they are underlaid by the Texan Beds dipping in the same direction from 24 degrees to 40 degrees; nor did he observe that the eastward dip of the Cambrian across a fault, but in the line of his section, is underlaid by a steeper dip of the same nature in lower Cambrian and Texan beds. Owing to these facts, which yield the strongest confirmation of the views here expressed, a single Packsaddle section is not enough to elucidate the structure. The Texan System can only be properly correlated by patching together such scraps of evidence as are scattered over our tract in these complicated upthrows. A very carefully prepared instrumental section is given in Figures 7 and 8, Plate II. This is the result of the field work of five men for two days in this limited area, besides the most accurate work of the same party for some time in the surrounding country.

The rocks of the Texan System are chiefly siliceous, but shales and limestones are not wanting. The data for a satisfactory lithologic classification are not yet collected, and it is impossible at present to adopt serial or epochal divisions of any permanent value. Roughly speaking, it may be said that there seems to be a fairly defined set of micaceous sandstones, almost equivalent to schists, but structurally more allied to sandstone. As a part of this,

* Were it not for my own firm conviction of the greater importance of "cycles of deposition" and "migrations of species" than merely local stratigraphy as elements of classification, there would be no need of any doubt upon these points. Maj. Powell's observations in Arizona and New Mexico, as well as Walcott's, all favor the idea that our Texan Beds are representatives of the shallow sea border of a great Algonkian ocean off to the west.

†American Journal of Science, vol. XXVII, 1884, p. 432.

or a later set, may be included an apparently underlying series of thinly laminated sandy shales, accompanied by peculiar sandy chloritic detrital sediments. These are followed by hard, compact, white laminated quartz rock, or quartzite, in beds associated somehow with ferruginous and schistose layers, which may be of intrusive character. Bluish and green and ferruginous shaly beds, in parts somewhat graphitic, but manifestly of detrital origin, occupy a position which is probably higher than the quartzites; and above these are limestones or marbles in beds of some possible economic value. It is often difficult in the field to distinguish the graphitic shale and marble, as a belt, from the similar lithologic set of the earlier Fernandan System. In hand specimens, however, the distinction is obvious. The Texan Beds are much less altered, as a rule. The graphitic strata are plainly derivatives of the pre-existing graphite schists, and the marbles are white or brown, instead of blue.

In justice to Mr. C. D. Walcott, who first announced the existence of unconformity between Eparchæan and Cambrian strata in this region, his appellation of Llano is retained for that one of the Texan series which will allow him this credit without seriously disturbing his later correlations.§

TAXONOMY OF THE SYSTEM.

Without intending any more permanent correlation than shall be justified by further investigations, a provisional adjustment of the Texan taxonomy seems to be reasonably indicated along the following lines:

Group (Era).	System (Period).	Series (Epoch).	Beds. (Central Texas).
EPARCHÆAN.	TEXAN, or ALGONKIAN?	3. *Packsaddle* (*Chuar?*)	Marbles and shaly beds.
		2. *Llano* (*Grand Cañon?*)	Quartzites and sandstones with eruptives?
		1. *Mason* (*Vishnu?*)	Sandy shales and schists.

IRRUPTIVES OF THE TEXAN SYSTEM.

In the Mason Epoch there seems to have been in Central Texas a comparatively shallow sea extending westward from near the present meridianal course of the Colorado River. The sediments of that littoral area are detrital deposits such as could readily have been accumulated from the degradation of the adjacent land of Laurentian age upon the east. The thin lamination or stratification of these deposits, and the frequent interpolation of granular

§ As a matter of credit, merely, the upper series might be the best thus designated; but, as Mr. Walcott has in several published sections made the Llano Series parachronous with Powell's Grand Canyon Series, it will save future annoyance to use his term for our Middle Series, as in this report.

basic layers are proofs of a somewhat vacillating sea border, and other indications of this appear in the lack of constancy in the vertical sections.

Irruptive rocks occurring now in this basal series of the Texan System may have been eruptive, intrusive, or extrusive, or of all three kinds, and it will not be a simple task to trace them all to their sources.

In the Llano Series the traces of interbedded basic eruptives towards the close of the epoch are rather more definite. This is especially true in the western exposures, although thinner interpolations, perhaps less numerous, occur as far east as Packsaddle Mountain.

The Packsaddle Epoch does not appear from present information to have been a time of volcanic activity in our region. The sea must have deepened considerably and gradually to have allowed the deposition of the shales and limestones. There does not seem to have been any landward encroachment of the sea, but rather a contrary movement in a small way. This foreshadowing of later orographic movements of much importance was, as far as we now know, unaccompanied by any extensive eruptions, although some observations leave a suspicion that intrusions of an acidic (granitic) magma were injected before the upheaval at the close of the Texan Period.

When the granites of this system are considered, a very difficult problem is presented, and one which may be more clearly stated, if not more easily solved, when the facts connected with the later history have been announced. It is proper to state here, however, that after the Eparchæan there ensued an order of conditions which opened a new arch-era in geologic times in this region.

CLASSIFICATION OF PRE-PALEOZOIC IGNEOUS ROCKS.

All through the great systems of the vast Pre-Paleozoic Eon eruptions of the basic igneous rocks must have been frequent and abundant. Granitic injections, from their fluidity, easily reached the surface in the earlier periods and furnished the material of the fundamental gneisses and schists, at least in part.

Gradually, as the later deposits accumulated, the intrusions and extrusions met greater resistances and smaller masses overcame the tension of the superincumbent strata. The highly acidic character of the suspended superstructure rendered the melting process less and less effective, and perhaps before the close of the Archæan the intrusion of granitic masses had practically ceased. Not so, however, with the basic igneous products, which at the same temperature were more fluid, and which would find escape at points not accessible to the higher lying and less dense acidic magma. This is explained

by the writer in a former publication, where the whole subject is more fully treated, with illustrations from another field.*

Finally the overlying, much crowded, and continually thickening capping of strata, although undergoing gradual metamorphism and becoming much folded, would only afford vents for either basic or acidic lavas in places where lines of weakness had been induced; and the granites could but rarely avail themselves of these.

The foregoing theoretical considerations are based wholly on the record of the rocks of our area, and they are borne out in fact in every important particular by all the observed igneous occurrences.

At the close of the Eparchæan Era we also part, so far as we now know, with the intrusive granites as a prominent structural feature. By this I mean that the compressed interstitial granites of the Burnetan, and the compacted quartzose granite dykes of the Fernandan, as well as the Texan type of tough feldspathic granite with moderate sized crystals, are not found associated with the later rocks, nor are their characteristic modes of occurrence repeated in more recent periods:

These generalizations will probably admit of better application when the results of microscopic studies are available. At present they may be scheduled as below.

Plutonism.	Vulcanism.		Strata.	Time.
Protrusion.	*Doubtful.*		CAMBRIAN.	PALEOZOIC.
Protrusion. *Extrusion.*	*Basic.*	Overflows gradually declining.	TEXAN.	EPARCHÆAN.
Protrusion. *Extrusion.* *Intrusion.*	*Acidic.* *Basic.*		FERNANDAN.	ARCHÆAN.
Protrusion. *Extrusion.* *Intrusion.* *Extravasation.*	*Acidic.* *Basic.* *Acidic.*		BURNETAN.	

Thus prepared, the great time gap which is represented by the denudation of the Texan folds before the deposition of the Cambrian strata will be found to be bridged over by leaves of history and by elements of structure hitherto unreported from Central Texas.

*The Geology and Vein Structure of Southwest Colorado. By Theo. B. Comstock. Transactions American Institute Mining Engineers, vol. —, 1886, pp. —. Also published separately in pamphlet form.

III. PALEOZOIC GROUP.

In view of the facts and conclusions yet to be given, it is important to call the reader's attention to the prior denudation of the land surface, and to the other conditions necessarily existing in order to sustain such life as was characteristic of early Paleozoic Time. The environment most consistent with known facts is about as follows:

(1) A subsidence below sea level of parts of our district, but not the whole; (2) an ocean temperature not essentially low, but cooled sufficiently to permit the growth of fucoids; (3) a near land area exposing just such Pre-Paleozoic Beds as are now uncovered in portions of Burnet and Llano counties; (4) lines of weakness or of tendency to crack and slide, causing liability to fault, along the three trends of the great Pre-Paleozoic uplifts; and (5) as a corollary of the preceding, a certain likelihood of subsequent irruptions approximately in the latest course.

The first three of these conditions will be amply verified by the facts adduced concerning the earliest Paleozoic strata, but the last two postulates may require a little notice here to elucidate some structural features now but little understood. Just prior to the Paleozoic depositions the latest or north-south trend was the "line of least resistance," and the one along which the greatest effect would naturally be given to the "pulsations" of the igneous magma. The long era represented by the widespread denudation of the Texan strata, and the later subsidence of the region shows that there might have been a tendency to outbreak along this latest Pre-Paleozoic trend. The facts are much confused, and probably more observations will be necessary to settle the interesting questions arising from the study of notes and collections.

The folding at the close of the Texan Period took place along two or more parallel lines, but the subsequent erosion must have left them with a slope towards the west, unless some important westward land elevation ensued. Of this there is convincing proof, although it is not easy to account for it except upon the hypothesis of Post-Texan igneous action. Some evidence of such a movement prior to the deposition of the Cambrian strata has been obtained from an examination of the country westward, but the structure is obscured by the resulting faults, and it is only proper now to say that granitic outbursts existed which might possibly have had much to do with the walling in of the sea in the earliest Cambrian Epoch.

3. THE CAMBRIAN SYSTEM.

There was probably a westward elevation of the land after the era of Eparchæan deposition, and the earliest Paleozoic Beds were laid down in a

sea to the eastward, with a western shore line of undetermined contour well beyond the middle of Llano County, at any rate. The indications are, however, that a large part of the old Archæan land areas were still above the sea. The shore line may have encroached upon these earlier highlands in part, but no evidence has yet been obtained of any Cambrian depositions west of the boundary line between Mason and Menard counties. Walcott believes that his middle and lower series of the Cambrian System are absent from this area, but, he remarks:

> The orographic movement that brought the Grand Canyon, Llano, and Keweenawan formations above sea level probably extended all along the central line of the continent, leaving the Atlantic area and the Great Basin of Utah, Nevada, Arizona, etc., areas of deposition during the existence of the *Paradoxides* (Lower Cambrian) fauna, and probably during the existence of the Middle Cambrian fauna, a break on the north or south permitting the latter fauna to pass into the western basin now covered by a portion of the Rocky Mountains.*

Without discussing other views of this author concerning which our evidence is not yet complete, it may be said that the above quotation is largely verified by my own observations in Central Texas; but for reasons which are to follow I can not agree with him that our area is deficient in representatives of the earlier Cambrian strata.

There is one remarkable stratigraphic feature, a series of topographic relief forms, which has been so much a puzzle that at times it has seemed well nigh inexplicable. This is, however, but the strongest of many warnings which this district presents against reporting hasty conclusions. Very gradually, after rejecting numerous hypotheses which were consistent with one or other of the facts, the writer has been enabled to get a clew to the history. Smoothing Iron Mountain and some of the neighboring elevations, certain of the peaks of the irregular group of the King Mountains, Sharp Mountain, Hickory Mountain, Town and Fox Mountains, Sandy Mountain, the eastern end of Packsaddle Mountain, and the Little Mountain near the Llano Falls, with probably a number of other eminences, are all capped by beds of massive sandstone or quartzite, sometimes underlaid by a coarse conglomerate of rounded white quartz pebbles in a red granular sandy or feldspathic matrix. Similar occurrences have been noted elsewhere, but subsequent upheavals have so much modified the original unconformity that it is often very difficult to detect the real structure at the contacts. But in many instances the field notes give hints of unconformity which can be readily explained by the aid of this section.

Putting together the various items, the following stratigraphic summary is found to be in harmony with them all:

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*Bulletin United States Geological Survey, No. 30, 1886, page 58.

1. At least two and probably three series of Cambrian strata are represented in Central Texas.

2. The character of the beds and their great thickness indicate gradual subsidence.

3. The tendency to folding along meridianal lines, which began at the close of the Texan period, continued during much of the Cambrian period.

(1.) HICKORY SERIES (LOWER CAMBRIAN ?).

Wherever I have seen good contacts of the Cambrian with the Texan strata, and in many places where the granites directly underlie the Cambrian, there is a set of beds which differ from the typical Potsdam sandstone. In every case in our region in which the upper contact of the terrane can be determined, there is an unconformity, although this is not always detected by casual observation. In most exposures the whole Cambrian System has been involved in Post-Cambrian uplifts, and this fact has caused previous observers to overlook the Inter-Cambrian minor unconformities. Probably the best outcrops of the lowest member of the series are those in the neighborhood of House Mountain, in the valleys of Hickory Creek and its tributaries, but there are also instructive exposures of higher beds in many other places, as at the summits of Smoothing Iron, Fox, Town, Sandstone, Sharp, Packsaddle, Sandy, Lockhart, and other peaks or elevated tables in Llano County. Besides these, there are patches in portions of Mason County, south of Fly Gap, between Mason City and the Llano River, and on Katemcy and Ranch creeks in the northern part. The last named exposures extend more or less into McCulloch County. An outcrop of the lowest conglomerate also occurs in Burnet County, about four miles from Burnet on the road to Bluffton, on a branch of Spring Creek, and what appear to be sandstones of the Hickory Series are well displayed at Cottonwood Spring, south of the same road, two miles farther west. The rocks begin at the base of the series with a coarse conglomerate absent from some of the sections, and they somewhat gradually change above to pebbly sandrock of medium fineness, with much local modification. In most cases false bedding and rapid variegation in color and lamination afford abundant evidence of littoral deposition. The basal conglomerate especially exhibits marked traces of in-shore beach accumulation from the degradation of the local subjacent rocks, and this feature gradually disappears in the higher strata, which have more the character of off-shore deposits made in shallow water. Some of the highest beds have the texture resulting from deposition in deeper water, regularly agitated. One very characteristic and persistent division is a massive white to buff fine pebbly sandstone near the top of the series, which is almost a quartzite, and which might be supposed to be burnt by igneous contact, if judged from some of

its outcrops. But the compact character is not a local feature like a certain other effect often observed where this stratum is in actual contact with protrusive granite. On the top of Sandy Mountain, and particularly on and about a little knob to the north of it, this Hickory layer has been considerably altered by heat so as to exhibit in different parts a gradual transition from above downwards, between the compact massive sandrock and a rock which most lithologists would class as a granite. Similar conditions exist on Sharp Mountain, House Mountain, Smoothing Iron Mountain, and elsewhere, but not on Packsaddle Mountain.

These facts taken together, in view of all the known occurrences of the Hickory strata, give the only lucid explanation of the situation, and one which has required more detailed study than almost any other problem connected with this district, and it has been puzzling to decide whether the two or more lines of protusion of granite of undoubted Post-Hickory age are the cause of the unconformity succeeding that epoch, or if they may not be of very much later date.*

But now it seems clear that the pulsations of the granite magma produced several broad folds in the Hickory strata, leaving certainly two great synclinal basins to be afterwards partly filled by the later Cambrian sediments. One fact, although not of itself a perfect proof of this postulate, affords excellent confirmatory evidence. This is the absence, *in every case*, of any later than Hickory sediments from the granite ridges now capped by them, excepting, of course, in the rare instances where uplifts in the later trends may have raised them to view. The thickness of the Hickory Beds, all told, can not well be above 200 to 250 feet. I should put it nearer 150 feet, judging from the best exposures, but in places where it is most altered by heat it is usually difficult to determine its basal members. On Packsaddle Mountain there is less than 100 feet of it between the Texan strata beneath and the higher Cambrian above, but the basal conglomerate is absent in these sections, as well as some coarse white false-bedded sandstone elsewhere observed. The Hickory Creek section is the only complete one yet observed, but some of the strata there exposed are more developed in other localities.

No fossils have been taken from any of the Hickory Beds.

(2) THE RILEY SERIES (MIDDLE CAMBRIAN?).

On Packsaddle Mountain, at the east end of the eastward projection, the

*This difficulty is enhanced by the apparent fault lines following the same north-south course, which, if they be true faults, must have originated as late as the Silurian period. For a long time the writer was unable to explain this feature satisfactorily, but now that the early Cambrian uplift is understood, other troublesome points concerning the later structure are made to disappear.

Hickory Series, dipping south about 15 degrees, and underlaid by the Texan Beds, dipping in the same direction 28 degrees, are overlaid by a thin capping of coarse grained, dark red, pebbly sandrock, dipping a few degrees northwest. This mountain is badly faulted, and contains, therefore, many puzzling features. Near the line of Walcott's section the structure is plainly indicated, but confusing unless very careful instrumental work be done. From the summit of the Texan System at the north base of the mountain to the top of the peaks and down upon the other side to the valley upon the south there is no such simplicity as Mr. Walcott has described from a rapid reconnoissance. That is not a good place to study the whole Cambrian System, although it does afford some hints regarding the subsequent dynamic history of our region. At the point of the westward extension of the Putnam Mountains, southeast of House Mountain on the right bank of Hickory Creek, there is the best possible exposure to explain what is not clearly exhibited in many other contacts. Here the granite, of a type characteristic of a Post-Cambrian (Silurian) uplift, has pushed up the conglomerate into a southeastward dip rising towards House Mountain, and this is overlaid by the set of conformable sandstones now recognized by myself as belonging to the Lower Cambrian Hickory Series. These sediments have been mistaken heretofore for the Potsdam sandstone, by the writer as well as others, but in this section the Hickory Beds are unconformably overlain by a thick series of strata which is itself unconformable below the Potsdam. From their great development in the Riley Mountains the name Riley Series is proposed for this set of beds, which presumably represents the Middle Cambrian Epoch. It is not always easy to distinguish them from the overlying series, although there is unconformity which can be made out in good exposures.

The conditions prevalent during the Hickory Epoch were somewhat changed in this Middle Cambrian Epoch, and the Riley deposits were laid down in synclinal bays between the ridges whose elevation began in early Hickory time. Probably that elevation continued during the Riley Epoch, for the strata are chiefly such as are deposited in shallow water, their thickness implying a gradual subsidence. The exposures indicate a different and more irregular shore line than any previously existing in the region, but there still was probably a considerable land area within our district. But an era of subsidence had begun for the surrounding area, which did not cease until a much later period than the Cambrian.

Fine exposures of what I now believe to be the Riley Series occur in the Sandy Watergap in the Riley Mountains; also over a wide area north of the Llano and Brady road west of Valley Spring, as far as Fredonia and beyond, spreading out through a large part of Mason County, where it is lost under Cretaceous deposits. It reappears, as if by erosion of the Cretaceous, in a

tongue in the valley of the Llano River, in Kimble County. Upon the southern side of the Paleozoic area of Central Texas there are also good exposures in the valley of James River (east bank) and in a few other places.

I do not yet feel confident enough of the true correlations of the scattered sections to set a sharp line of demarkation between this series and the one above it. There is a point assumed as a parting in the field which may prove to be an easily traceable horizon, but this would be very difficult to define verbally so that no one could mistake it. Many fossils have been collected, and such attention as has been possible to give them thus far has tended to confirm the judgments based upon the stratigraphy. There is the widest variety in the thickness of the beds, owing to the local inequalities left by erosion and subsidence prior to deposition. This makes it very difficult to give a detailed section which will be characteristic. The maximum thickness is probably from 300 feet to 400 feet.*

In general the rocks are sandstones varying in color from light red and shiny black to brown and yellow, and even white. These conditions are very interesting when considered in connection with the *locus* of formation in each case, for they can usually be explained by reference to the underlying rocks or to the geographic distribution of the color. Dark brown and chocolate beds are most persistent, the white being confined to areas adjacent to the oldest Archæan rocks. "Sand Castle," one and a half miles northeast of Valley Spring, and "Sand Fort," a similar eminence in the upper part of Cold Creek valley, are examples of the latter class, although it is not certain that they belong to the Riley Series, as I now suppose. The view of the Riley Beds in Sandy Pass, as shown in Plate IX, gives a good idea of the cliffs of sandstone outcropping there. Fault lines of two or more trends are prevalent in this region. In the engraving one of these courses is nearly in line with the face of the cliffs, and another cutting it at an angle of sixty degrees comes in at the right. Sandy Creek is following both faults in its course. These breaks are of later date than the Cambrian. The rocks here are the bright red and white variegated soft sandstones, running up into buff calcareous shales above, the section in the lowest part being much like that of Sand Castle and Sand Fort. Above these, in the weird Glen Gap, a little behind the cliff at the right, a capping of different rock occurs. This is the dark brown granular rock already referred to, and in this segregations of *limonite* and *hematite* are common, and occasionally enough manganese stain to give them externally a jet black color. Some compact chocolate colored limestones are associated

*The field work of 1889 was devoted so closely to the Pre-Paleozoic rocks that enough time was not left for a complete examination of the later sediments. Although much evidence has been collected bearing upon points here treated, just conclusions can not be drawn in detail without more study with especial reference to the elucidation of doubtful points.

CAMBRIAN CLIFFS—SANDY WATER-GAP, LLANO COUNTY.

with these near the summit. In portions of what I have taken to be Riley Beds the ferruginous segregations are very numerous. These are not always commercially valuable, but there are extensive strata of this horizon which in certain localities contain enough iron to be profitably worked. We shall discuss this feature and the distribution of such "bonanza areas" in another place. (See Part II.) The cause of such occurrences may be readily explained.

The Mid-Cambrian life of the Riley Epoch has not been distinctly outlined for this region. Walcott thinks it absent from our rocks, but I have taken forms closely allied to *Lingulella cœlata*, Hall (sp.), *Lingulella ella*, H. and W., *Hyolithes americanus*, Billings, and *Orthis? highlandensis*, Walcott, besides *Eocystites?* and undetermined sponges and fucoids. These do not necessarily indicate a middle Cambrian fauna, but they do not disprove it; for the known species all occur elsewhere in Walcott's Middle Cambrian, although not wholly characteristic of this series. There are no known places in the Riley Series where the beds are suitable for the preservation of the *Pœcillopoda* (including Trilobites), and no such fossils have yet been found. Not far above this, however, in the higher Cambrian Series, Trilobites are very abundant, and they are not *Paradoxides* nor *Olenellus*.

(3) THE KATEMCY (POTSDAM) SERIES (UPPER CAMBRIAN?).

As the writer now views the matter (provisionally), there is a distinct set of red sandstones in position above the highest beds of the Riley Series, with at least an overlap, if not a dynamic unconformity, at the contact. Very possibly further examination in the field in 1890 may render necessary some changes in localities, as it is by no means certain that a well marked boundary exists at the base of the series in all exposures. But assuming such a line, temporarily, at the junction of the chocolate limestones of the Riley series with the rocks usually overlying them in good sections, there will generally be found some stratigraphic record of a changed area of deposition.

From my present limited knowledge of the life of the Cambrian in Central Texas, I dare only report that a conviction has been growing of its probable transitionary aspect, although some few types may be found in only one of the series. The final separation of the Middle and Upper Cambrian will probably be based upon the horizon of the lowest occurrences of *Lingula*, *Dicellocephalus*, etc., and my present opinion is that the boundary here drawn is consistent with such a paleontologic classification of the strata. At any rate, my own observations, stratigraphic and paleontologic, are in harmony with this view.

We may conveniently adopt three divisions for the Katemcy Series, based

upon persistent lithologic characters, viz.: A, the *Potsdam Sandstone*, or *Lingula grits*; B, the *Potsdam Flags;* and C, the *Potsdam Limestone*.

DIVISION A. THE POTSDAM SANDSTONE.

The basal rocks of the Katemcy (Potsdam) Series differ from their predecessors in a way which, of itself, implies the degradation of the latter to produce them. They are not always as fine-grained as some particular strata of the Riley Series. but they are generally more comminuted, and they ordinarily have a yellowish-red color or a paler tint than the Riley Beds. These and the higher beds are well exposed in the valley of Katemcy Creek, Mason County, from which outcrops the serial name is taken. Complete sections of this comprehensive set of beds are not usually to be had in a single district, owing to the later faults which have broken the continuity of the strata in two, and sometimes three, directions. By putting together the detached sections, as well as may be without more detailed paleontologic study, there seems to be a succession of the following character, beginning below:

1. A red, rather friable sandstone, often containing *Lingulæ*, and sometimes more or less irregularly charged with ferruginous segregations, chiefly *Limonite*. Thickness variable, say 50 to 100 feet.

2. A white sandstone, similar in texture to the foregoing; thickness, 10 feet to 20 feet.

3. A very friable greensand, perhaps not always present, but as much as 20 feet thick in places.

DIVISION B. THE POTSDAM FLAGS.

A set of thin greenish shales and shaly limestones sometimes overlies conformably the series of grits described above. There may be a doubt of their presence in some sections, but they are well developed on Morgan Creek, Burnet County, where they are fossiliferous. The division is not a very prominent feature of any exposure, but its prior existence can usually be detected by the occurrence of a conglomerate at the base of the higher division, which is made up of the waterworn flaky fragments of a similar material. The flags may be allowed a maximum thickness probably of 50 feet.

DIVISION C. THE POTSDAM LIMESTONE.

The highest Katemcy division begins, at the base, with the compact greenish conglomerate above mentioned, of which there is usually 50 feet, with variations in thickness according to the relations of the sections to the oldest shore-lines. There must have been important vacillations of the sea-border during the Katemcy Epoch, but they seem to have been more in the nature of tidal incursions and excursions than local changes of land level. As before remarked, however, there is some evidence of a continuance to this age of

the meridianal uplift which began after the Texan Period. Overlying the conglomerate there is a set of limestones, usually thickest where the former is thinnest, and *vice versa*, but in some places both are well developed. Walcott reports 310 feet of "Potsdam limestone" in Packsaddle Mountain. Among these beds he probably included the flags, and perhaps some of the beds of our Middle Cambrian, which might have been mistaken for them in that section, owing to blind faults not discoverable without some detailed study. He is wrong in putting 90 feet of Potsdam sandstone above this limestone, for it is immediately covered by Silurian dolomite. There is a continuous section of the Upper Katemcy Beds north of Bauman's, extending from the east bank of Cold Creek up to within about 50 feet of the summit of Sponge Mountain, where it is capped by the Silurian. In this exposure there are 200 feet of the limestones, surmounting 50 feet of the conglomerate interstratified with limestones. Much of the limestone is impregnated with greensand particles, and the whole is laminated and largely fragmental.

Several well defined fossiliferous horizons, containing especially numerous mutilated trilobite remains, are included. An interesting discovery is the occurrence of *Foraminifera* in abundance in some of the greensand limestones. The greensand beds of the lowest division may contain similar fossils, but I have as yet been unable to detect them there. They occur in some of the chocolate and red sand rocks, of uncertain horizon, but apparently of Potsdam age. Practically the same sections exist in many parts of our district, but the basal contacts are by no means regular. On Deer Creek, in the southwest corner of San Saba County, the Upper Katemcy Beds (Potsdam limestones) seem to be resting conformably upon the Lower Katemcy (Potsdam sandstone) basal members. At Camp San Saba, at the mouth of Katemcy Creek, the conglomerate appears to be nearly absent, although it comes out in full force again in supercontact with the Middle Katemcy strata (Potsdam flags) only a little west of the town. The junction with the Silurian is no less variable. All these facts have an important bearing upon the geologic history, but enough has been written to make the salient features understood, and further discussion must be left until a more convenient opportunity.

TAXONOMY OF THE SYSTEM.

Group (Era).	System (Period).	Series (Epoch).	Division (Age).	Beds.	Life.
III. PALEOZOIC.	4. CAMBRIAN.	3. KATEMCY (UPPER CAMBRIAN).	*c. Potsdam Limestone.*	Limestone, Calcareous conglomerate.	*Orthis*, *Dicellocephalus*, *Lingula*, etc.
			b. Potsdam Flags.	Shales.	Fucoids, Sponges, etc.
			a. Potsdam Sandstone.	White and Red Sandstone.	*Lingula.*
		2. RILEY (MIDDLE CAMBRIAN).		Chocolate Limestones, Calcareous Sandstones, Sandy Shales.	Part of Walcott's Mid-Cambrian Fauna.
		1. HICKORY (LOWER CAMBRIAN)		Massive Sandstones, Coarse Conglomerate.	Unknown.

IRRUPTIVES OF THE CAMBRIAN PERIOD.

Heretofore we have only been able to study the irruptives as concomitants of the strata in which they occur, making determinations of their time relations to each other, and offering hypothetical opinions for the most part as to their geologic ages. Perhaps we shall yet be able to clear up many doubtful points concerning the ancient dynamic history; but there are manifest obstacles in the way of deciding closely whether an igneous ejection in the schists may have been intrusive, extrusive, or only protrusive. Fortunately not much is now dependent upon these minor issues in our stratigraphy, although a full knowledge of the character of the special plutonic and volcanic products may eventually be essential to the solution of important problems.

In the Paleozoic rocks there are less confusing contacts with the granites, and I do not know of any basic lava flows nor of any other than protrusive granite masses later than the Eparchæan. There are granites which now extrude from the Pre-Paleozoic rocks, but these can always be traced into such relations with Paleozoic Beds that their Post-Texan age can not be doubted. Reference has been made to probable extrusions of granite along meridianal belts, accompanied by subsidences of intervening areas, at the close of the Lower Cambrian. The course of these uplifts had been marked out previously by much denuded and weakened folds in the Texan strata. The metamorphosing effect of the outbursts was not marked, although, as they frac-

tured these deposits in places, they probably became extrusive from the Hickory Series.

The granitic magma must have been more plastic than fluid, because it did not entomb any of the schists, and although its structure now is roughly columnar, or semi-fissile, it appears as if it had cooled somewhat rapidly without great pressure.

If any further protrusions took place at the close of the Middle Cambrian the action was not pronounced over all the region of the Riley deposition. But there are places where some such factor seems necessary to account for the structure exhibited, as in the valleys of Little Llano and Cold creeks, in Llano County, and perhaps also in the Beaver Creek region and elsewhere. Of very common occurrence in the country between Smoothing Iron Mountain and the King Mountains, particularly along the course of Cold Creek, are what may be appropriately styled "sandstone dykes." These are simply the upturned edges of broken parts of the massive sandstones of the Hickory Series. They are not confined to the north-south trend, but that is a prominent course. Sometimes erosion has exposed the granite in juxtaposition with the dykes, and in many places fine springs flow out from the contacts. I have noted many of these projected sandstone ribs and have not found one emerging from rocks of later date than the Cambrian, although their courses are not confined to Pre-Silurian trends. As they do occur cutting through the beds of the Katemcy Series, there was probably a diminished uplift at the close of that epoch; but in our district it was not seriously felt, unless granitic outbursts and some faults off to the northwest may yet be traced to this period. From observations made in western Mason County, I am now inclined to believe that this Post-Cambrian throbbing was the weakened eastern border expression of a prominent dynamic factor off to the west, beyond our district. The northwest course of certain dykes in the Cambrian needs further investigation, as its importance was not sufficiently appreciated in the field studies. The writer left the field fully convinced that the trend of north 36 degrees west involved only Pre-Algonkian rocks, but he is now of the opinion that a reopening of that outlet was partially accomplished at a later period.

5. SILURIAN* SYSTEM.

It has generally been believed that the Paleozoic rocks of Central Texas form an unbroken geologic group which accumulated in an open sea cover-

*The term Silurian is employed in this report as a systemic name equivalent to the *Lower Silurian* of American geologists, it being probable that a new name will soon be adopted for the so-called Upper Silurian. See Dr. J. D. Dana's remarks upon this subject in Bulletin Geological Society of America, vol. I, February, 1890, page 40.

ing the whole area as late as the close of the Carboniferous period. Previous observers have looked upon the district as an eroded tract exposing the Paleozoic Beds only by the denudation of a thick mass of Cretaceous strata. The uncovered Pre-Silurian rocks, by whatever name heretofore known, have always been regarded as relics of this character. Mr. Walcott, who was able in his short stay to determine the great unconformity at the base of the Paleozoic, and to satisfy himself that some of the granites were Pre-Cambrian, left the subject in about the same condition. Mr. Hill, although pointing out the probability that later granites exist, which have introduced irregularities into the structure, has been strongly imbued with the idea that the Cretaceous strata crossed and covered the region, and that, as stated above, denudation has chiefly made the topography what it now is.

The facts which have led the writer to adopt a contrary opinion regarding the Pre-Silurian periods have already been given. The Silurian System, in its lithology, and to some extent in its stratigraphy, presents new issues. On account of subsequent events it is not so easy to make out what may have been its shore lines while depositing; yet, when we get a chance to study its contacts with the underlying strata, and to compare its texture, its distribution, and its dynamic history with those of the Cambrian, the idea of a Silurian land area within the district is confirmed. Two facts which bear most strongly upon this question are the following:

(1) The inauguration of the Silurian period by an epoch of shallow water sedimentation, especially westward. (2) The deposition of later Silurian beds unconformably upon eroded Cambrian strata. Items in point will be given as we proceed. Neither of these important stratigraphic elements has heretofore been reported.

Close correlation with the Silurian strata of other regions is not now possible, hence, as before, provisional local names are used to designate the sets of beds comprised in this system in Central Texas. The lithologic and paleontologic transition from Cambrian to Silurian is not violent; at the same time there is an evident stratigraphic unconformity in most sections. The Silurian has not been studied with the care which has been bestowed upon the earlier rocks, as it has required much labor simply to block out the area covered by the system. Again, the purely structural determinations and the tracing of contacts with later strata have consumed much time. This work is not yet completed, but enough is known to report that the area hachured with horizontal lines upon the progress map is very largely covered by the Silurian rocks. The final map will show an inner border of Cambrian rocks of irregular shape, much broken by downthrow faults with Silurian now at surface. But this belt now occupies only a small portion of the pre-Carboniferous Paleozoic area of our district. A rough classification of the Silurian Beds

is possible, although we cannot at present make good paleontologic separations to correspond with the stratigraphy. Much of what follows upon this subject must necessarily be held provisionally.

(1.) THE LEON SERIES (CANADIAN?).

The Llano and San Saba rivers run for many miles in parts of Mason and McCulloch counties through canyons cut in dolomites, the upper layers being pure white to gray and light buff, compact and very tough, underlaid by shaly dark buff dolomites. and these again by thick siliceous magnesian limestones, weathering black and roughly pitted upon surface exposures. These last beds lie conformably upon another set of buff or yellow dolomites, perhaps three hundred feet in maximum thickness, which are more sandy in character and of shaly structure. The relations of these strata are such as to make it probable that they are basal Silurian members in this region, although our investigations have not extended over all the district in which they occur.

There is a peculiarity, as yet unexplained, which makes the co-ordination of the north and south border sections a difficult matter. This is the irregularity of the Cambrian surface contact. Not only do the later sediments encroach upon the eroded foundation in such manner as to present contacts with almost every Cambrian horizon, successively, in different places; but the various Silurian strata have also individual basal contacts with the Cambrian. In addition to this, the direct tracing of the section is rendered nearly impossible by frequent breaks in continuity due to downthrow faults.

The local name Leon Series is proposed tentatively to include all the sets mentioned, which thus taken together, may be generally described as siliceous magnesian limestones of the common physiognomy of the Canadian rocks of other regions. This whole series is well exposed along the lower valley of Leon Creek, in Mason County.

As a skeleton for future work the following division names are announced: A. The *Beaver Division*, or Lower; B. The *Wyo Division*, or Middle; and C. The *Hoover Division*, or Upper.

A. THE BEAVER DIVISION (LOWER CANADIAN?).

The basal buff dolomites are a prominent feature of the scenery in the river canyons wherever they are exposed, and of the great escarpment upon the left bank of the Colorado, north of Morgan Creek, and near the mouth of Beaver Creek. They appear also in partial exposures upon Cold Creek and in the east-west escarpment following near the north line of Llano County. Outcrops in similar cliffs, protected by the massive blue limestones, occur in fault lines and erosion scarps in the canyons of the Llano River and of Little Bluff,

Bluff, Mill, Rocky, and Leon creeks, in the southern part of Mason County, as well as in tributaries on both sides of the San Saba River, in San Saba, McCulloch, and Mason counties.

The Beaver Division, as here defined, is intended to include the lowest two lithologic members of the Leon series, viz.: (1), the *Cavern Subdivision*, and (2), the *Bluff Subdivision*.

(1) The *Cavern Subdivision*, as its name implies, is often pierced, in the cliffs, by small caves and grottoes, and chambers of larger size are frequent in the inaccessible precipices. Some caverns of large dimensions are known in districts where these rocks cover large areas. Several of these have been explored in Burnet County, and one which may be in this stratigraphic division has become noted commercially as a large producer of "bat guano." This will be described hereafter.

The rocks of this set are chiefly the yellow sandy dolomites of the Silurian base, but in the upper third of the exposures there is usually an interpolation of a few feet of dark dolomite, similar to the next higher subdivision. In some cases the transition is gradual enough to prevent establishing any but an arbitrary line between these two sets; in other places the distinction is more obvious, and, rarely, there may be a sudden change of character. Although there are thus these minor discrepancies, due to the fluctuations of shore lines during the deposition of the Beaver strata, and although the general result was a transfer of parts of the district from near-shore to deep sea conditions, there is such a constant association of the Cavern and Bluff Beds in the sections, and such a close conformity between them, that they seem to belong together in any appropriate classification.

The yellow rocks belonging to the Cavern Subdivision are not wholly sandy, but there are many of them which have a fine-grained arenaceous character, while some of them have irregularly alternating layers of calcareous and siliceous composition. Like all the rocks of the Leon Series, they are, first of all, magnesian limestones; but they have enough of the sandy nature, especially in the nearest contacts with the Potsdam sandstones, to make their weathering, in form and *talus*, suggest an approach to sandstone characters. This is less observable in the higher strata as a rule. Three hundred feet is probably a liberal allowance for the thickness, including the massive blue dolomite and the yellow overlying beds immediately below the Bluff Beds.

There may be some lithologic justification for correlating the Cavern strata with the lowest Calciferous rocks (Calciferous sandrock) of Missouri, as has been done by Shumard and Glenn, but such generalization, to my mind, is not in keeping with the spirit of modern science. The fossils obtained have not been numerous, and very few of them are in a good state of preservation. Fragments of Trilobites from a Cold Creek section may be *Bathyurus;* some

Fucoids? resemble a *Palæophycus;* other raised markings are very probably *Stromatocerium;* a much weathered impression has somewhat the appearance of a Lamellibranch of early type; and one form is like *Leperditia* (not *L. anna*, Jones, but more like *L. Canadensis*, Jones, of the Chazy.) It is probable that special effort next season will enable us to collect more characteristic specimens from the fossiliferous beds which are now known to occur in this subdivision.

(2) *The Bluff Subdivision.*—The blue magnesian limestones are commonly coincident in distribution with the buff dolomites, and sometimes they form mesas or plateaus, but in many places they are still covered by the later rocks. They occur usually in only a few beds, each from 5 to 20 feet in thickness, perhaps 60 to 80 feet in all, as a maximum, but often much less. There can be no doubt concerning the stratigraphic relation of this set of beds to the strata above and below; but as no fossils have yet been discovered in any of them, there is now no alternative except the adoption of a lithologic classification, which is here made to correspond as closely with the facts as present knowledge will permit.

The rocks of this upper subdivision are dark magnesian limestones, as seen in the bluffs, and they are usually preceded by brown beds of rather dense crystalline granular texture. Upon fresh surfaces of fracture the Bluff Beds are gray or bluish and rather compact, but they weather black, and are frequently roughly pitted upon exposed surfaces. No fossils have been discovered in them to the writer's knowledge.

B. THE WYO DIVISION (MIDDLE CANADIAN?).

The name Wyo is adapted from the well known cattle brand (Y O) used in the Blue Mountain region along the course of the James River in adjoining parts of Mason and Kimble counties. The Wyo Division is not clearly proved to hold the stratigraphic position here assigned it, although I have always found the beds lying directly beneath the next higher Hoover Division when both occur in the same section, and there is no support to any other designation, at least in my notes and those of my assistants; but in the district where the best exposures occur, faults and other complications make it wise to draw conclusions with great caution. I prefer not to commit myself to many details until more study has been given to the sections. However, in the San Saba Canyon, west of the Block House crossing, and upon the James River near the boundary between Mason and Kimble counties, the relations of this division to the subjacent rocks are apparently what has been given here. The beds of this division are particularly well ex-

posed on Glen Creek,* also along the James River southward, where their thickness is probably as great as anywhere in Central Texas.† Other outcrops occur in the San Saba River valley in the northern part of Mason County. The same beds appear in goodly quantity in the Silurian escarpment which runs irregularly east and west along the upper bluffs north of Fairland Postoffice in Burnet County. This division sometimes directly covers the Potsdam limestone division of the Katemcy series, but it has not as great a distribution over that terrane as have some of the earlier and probably some of the later beds. There is considerable variation in thickness in different sections, but the maximum, so far as observed, can not be much above 60 to 80 feet. The rocks are chiefly brown weathering dolomites or semi-crystalline limestones of dark reddish or purplish color, becoming sandy or granular above. For a general description, perhaps the expression brown, shaly, magnesian limestones will be most applicable. The beds are rather thinly laminated, and they usually weather into craggy cliffs wherever there is any opportunity for such a topographic feature. This is well shown along a part of Hudson Creek, north of Camp San Saba, McCulloch County, and in the valley of James River and some of its tributaries in Mason County southwest. This last area is continued northward across the valley of Mill Creek; thence beyond the Llano River to the lower valley of Leon Creek. Good exposures also occur over much of the eastern edge of our district, but in places the higher beds seem to have overlapped so far as to cut out the members of the Leon series.

Making the base of the Hoover Division at the horizon assumed provisionally in this report, no fossils have been found in any rocks which are certainly referable to the Wyo Division. In a number of widely separated outcrops search has been made without success, but much more detailed work is necessary before abandoning the quest. Badly broken Trilobite remains occur in beds on Leon Creek which may belong at the base of this Division, but the lithologic characters caused me to consider them Cambrian in the field.

C. HOOVER DIVISION (CHAZY?).

Overlying the Wyo Division of the Leon Series in many exposures, but

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*This creek enters the James River from the west about two miles below the mouth of Devil's River, near the north line of original survey No. 334, Mason County. As it has not previously been named, it will appear upon our maps as Glen Creek. This name is suggested by the gorges and coves along the crooked stream course, but it is also true that a Mr. Glen has recently occupied the ranch house in Schreiner's pasture, directly in the path of the creek.

†The writer has reserved the study of the upper valley of James River for the field season of 1890. Enough was seen in 1889 to make it very probable that results of very great interest will accrue from instrumentally accurate sections made in that region.

often itself resting directly upon Potsdam limestone or sandstone, there is a well marked aggregate of very fine-grained compact limestones, or white or grey dolomites. To some of the strata the name "Burnet Marble" has been applied by the earlier geologists, from the great development of the series near the town of Burnet, and in the neighboring portions of Burnet County. In Hoover Valley, along the Silurian escarpment at the sources of Webster Creek and Peters Creek, the beds are well exposed, and much hope has been entertained by the citizens that the most uniform beds may possess commercial value as a "lithographic stone." The results of tests are given in another chapter. The structural feature of most interest is the apparent unconformity between the base of this Division and the summit of the Wyo Division. This is not necessarily in the nature of a catastrophic break, but more probably of gradual subsidence; for the contact in the James River valley and elsewhere is made through beds of passage partaking of the characters of both sets. Some of the strata which are here regarded as basal members of the Hoover Division are in composition mere transitionary relics of the Wyo type. These, however, usually appear more like the Wyo beds at a distance than upon close inspection. Even the uppermost wave-marked layers have the texture of the limestone in part, thus standing below the assumed base of the Series, with a mixture of Wyo and Hoover characters. In places where the later shore line has been pushed inward beyond the edge of the earlier coast, so as to bring the lower contact into junction with the Potsdam limestone, the basal members are often pure limestones. At other contacts of this kind, perhaps more common, the connecting beds show evidence of a semi-fragmental origin, with limestone components of both Cambrian and Silurian types. These last can hardly be classed as conglomerates, but they simulate them on fractured surfaces, in a peculiar manner. The appearance is what one might expect from deposition in moderately deep water subject to ebb and flow of fine sediments.

Some of the facts seem to imply a throbbing or slight uplift in portions of the district, accompanied by subsidence in other places, at a time subsequent to the deposition of the passage beds, and antecedent to the epoch of Burnet marble sedimentation. Were it not, however, for certain northwest dikes, breaks, and dip courses which are best explained in this way, it might not have been thought necessary to seek any other cause than that of differences in depth of the sea in different places at one time. Still this could not alone account for all the facts observed.

There is a very convenient horizon for the provisional separation of the Wyo and Hoover strata, although future studies may not warrant the establishment of a stratigraphic serial line at this point. This is at the lowest known fossil horizon above the Wyo crags. Fortunately for our purpose

wherever the crag dolomites have been observed beneath beds of the Hoover facies, there is a set of fossil-bearing beds. With more or less of variety in the different localities, and with no certainty that the fossil strata, or any of them, will be found at the Hoover contacts with the Potsdam, no Wyo-Hoover contact has yet been observed without a fossiliferous layer. A set of fucoid-bearing beds above a wave-marked set affords the most suitable dividing line for our purpose.

Beginning with the dark fucoidal limestone, the Hoover Division gradually passes upward through thin, slabby, fossiliferous limestone of the compact Burnet marble texture, becoming thicker, more pure, and lighter colored above, into fine-grained, gritty, crystalline dolomites, forming transition beds to the cherty San Saba series above.

The fucoid beds are thin, brittle, and of irregular texture. In the James River valley, in Mason County, near the Kimble County line, these rocks cover a very wide area, and they are also displayed as the surface terrane over much of the San Saba valley in Mason County. The markings are disposed in graceful curves, and they seem to correspond in generic characters with *Bythotrephis*, Hall, but the large size, habit of growth, and other specific features remove it from *B. gracilis*, Hall, which it resembles in a very general way. Above these, in the whiter layers, sometimes parts of the same or adjoining slabs, are very abundant coatings of a reddish brown, branching fucoid? of different character. This more closely agrees with *Bythotrephis succulens*, Hall, and it occurs in excellent shape for study. These fucoids lie in interstices of the wavy lamination, so that they weather out to the best advantage. Still higher, but usually beginning near the fucoidal beds, there are grey and dull brownish "Burnet Marbles" containing animal remains, largely Gasteropods, but with occasional forms like *Eocystites* and fragments of small undetermined crinoids, etc. One prominent form of Gasteropod, appearing in section at the surface of the weathered grey beds, is a *Maclurea*, near *M. logani*, Salter. Upon Arrott's Branch of Little Llano Creek and farther south, the partly calcareous Wyo beds are separated from the Hoover Division by a kind of chalky limestone, largely made up of globules with almost indeterminate markings. These are a little variable in size, averaging perhaps one-fourth to one-half an inch in diameter, or more. It is possible that they are *Malocystites murchisoni*, Billings, of the Chazy age.

Above these fossil horizons the Hoover beds become more pure, lighter colored and thicker, without lamination planes. As a rule, however, the two kinds of beds do not occur in a continuous vertical section, from which we may infer that they represent the nearly coincident accumulation of shallow water and deep sea deposits in different localities. Some observations lead to the supposition that an important stratigraphic break occurs at the summit

of the Burnet marbles, and it may be that this should be taken as the Canadian-Trenton contact in Central Texas. Our studies have not yet gone far enough to settle this question. In the upper part of the Hoover Division, in McCulloch and San Saba counties and elsewhere, the marbles are evenly or unevenly colored shades of blue, red, brown, and yellow, producing in some cases a beautiful variegation in the same stratum, at other times uniform tints, exhibiting alternations of color in sets of strata.

(2) THE SAN SABA SERIES (TRENTON ?).

Upon the southern border of the Central Texas Paleozoic region the Cretaceous strata lie for the most part directly upon one or other of the terranes below the summit of the Leon series. Before the former were deposited erosion had left a foundation of irregular outcrops of the various beds from Archæan to Silurian at least, and the Mesozoic subsidence involved enough of the Central area to allow the early Cretaceous sea to bathe the outskirts up to the inner rim of Silurian and earlier rocks. Upon the northern border of our portion of the Central region the Cretaceous overlies the Carboniferous, and a broad area of the higher Silurian strata is now uncovered in that region. In the west and south, therefore, there are few exposures of Paleozoic rocks higher than the base of the Hoover Division, but in the east and north the whole Silurian System is well developed. The most complete section will be obtained along a northwestern course from near the mouth of Beaver Creek, in Burnet County, across the county of San Saba, passing west of Latham Creek by way of Deep Creek to the San Saba River and beyond. From the excellent field for the study of the higher beds, covering a vast area in San Saba County and in much of the San Saba River valley, including territory in the neighborhood of San Saba City, no more appropriate name can be given to the Series. We need more knowledge of what lies out beyond the southern edge of the district surveyed in 1889, but it is a very significant fact that only one or two exposures (upthrow faults) of the San Saba Series west of the Colorado River have been reported, south of the divide between the San Saba and Llano rivers. A straight line drawn from the southeast corner of Concho County to a point in Burnet County four miles south of Burnet will lie south of all the exposures. Upon the southern border the elevation of the same stratigraphic horizon is full 300 feet greater. These features of the present topography are the results, in large measure, of events of Post-Silurian date, and yet they have a very important bearing on the study of Silurian geology, for it is evident that even the latest faults in a region like this would be guided into courses materially dependent upon previous history. The beds of the San Saba series consist of dolomites and chert. No stratigraphic breaks indicating dynamic unconformity have been

anywhere observed, but there is good warrant for dividing the series into two divisions. These are here named: A, *The Hinton Division*, and B, *The Deep Creek Division*.

A. THE HINTON DIVISION (BIRDSEYE, BLACK RIVER, AND TRENTON?)

The distribution of the lower division, if such it really be, is apparently very much restricted within the limits of our district, and yet is represented by thick deposits of unusual interest. The region of greatest deposition seems to have been in the northwest, and the present positions of the beds give vague hints of gradual movements of elevation and depression along lines which have not been clearly defined.

The following generalized section is made up from different exposures south of the San Saba River in San Saba County, in the valleys of Deer and Hinton creeks, one of the best regions for study. This agrees well, also, with the partial outcrop on Cold Creek, in Llano County, and with an incomplete development of the series on Hudson Creek, north of Camp San Saba, and westward in McCulloch County. Beginning below there are:

1. A transition set of siliceous limestones of variable thickness, and somewhat indefinite composition, making it difficult in some sections to draw a sharp line. Occasionally a semi-conglomerate of limestone fragments occurs here, as on Cold Creek, at Sponge Mountain.

2. A pink, white, or mottled red and white limestone, with crystalline facets, agreeing well with the typical Birdseye Limestone of New York and elsewhere. Thickness usually not above 15 feet.

3. Tough, commonly dull gray to brownish, crystalline dolomites, weathering gray, usually in some variety. In this set, two miles west of San Saba, on the road to Brady, I took from a block of limestone *Maclurea crenulata*, Billings, and *Favosites*, sp.?

4. Sometimes a set of calcareous shaly beds, 15 to 20 feet.

5. A fossiliferous horizon with a solid pavement of large sponges—*Stromatocerium rugosum*, Hall, or a near ally. In some cases there are beds of these fossils at least 10 feet thick.

6. An aggregation of sandy calcareous shales or slabby dolomites, usually forming cliffs or craggy outcrops; 25 to 30 feet.

7. A sponge bed made up of strata of slabby character, containing *excessive quantities* of what seems to be *Stromatopora concentrica*, Hall; from 15 to 20 feet.

Here the section stops in many instances, and a hiatus in our knowledge occurs which has not been completely filled, owing to great faults and through lack of notes upon any one exposure, including these beds with both higher and lower beds. But there is reason for assuming the base of the higher division to be just above the summit (No. 7) of this section. In the plateau

south of Burnet a succession of beds occurs which is equivalent to the Deep Creek division, and this is underlaid by the Hoover division of the Leon series, with very few, if any, of the Hinton Beds. The base of the former there, as elsewhere, so far as now known, is always a gritty fine-grained dolomite, here assumed as the lowest member of the highest Silurian division.

B. DEEP CREEK DIVISION (HUDSON? OR NIAGARAN?).

Deep Creek and its branches, especially in the lower stretches, exhibit a peculiar topography of a type characteristic of the massive terrane which crowns the Silurian system in Central Texas.

This is, *par excellence*, the siliceous division of the Paleozoic in our district, the beds being solid masses of cherty limestones mingled with gritty dolomites and tough magnesian limestone, the last often containing abundant segregated semi-geodes of drusy quartz. The distribution of the Deep Creek strata is as unique and interesting as the texture and composition. Reference has already been made to the ancient shore line of the Hinton age which followed along the southern edge of San Saba County, with a southward prolongation or bay extending down into western Llano County and another into western Burnet County. The representative of the American Trenton? Sea had a somewhat different coast in this region. In Burnet County part of the Hinton land surface became depressed so as to allow deposition over a considerable portion of that area during the succeeding age. The western bay in Llano County retreated northward but slightly, although the shoreline in San Saba County and further west was apparently pushed out northward in places and extended back southward in others.

Long faults, which can be traced in some instances for many miles, and subsequent denudation to an even grade, have left the field in very bad shape for rapid study. Much remains to be done in piecing out gaps in the record but the section given below is so often repeated that it may be regarded as a fair presentation of the succession of strata. In ascending order there are:

1. A stratum of gritty, fine-grained, saccharoidal, light grey, or slightly yellowish, highly siliceous dolomite, weathering dark grey. Included in this, or above it, are similar but tougher dolomites, with numerous scattered patches of drusy quartz following surfaces of a somewhat regular, crumpled, or molded pattern. The forms and disposition of these infiltrations, although they are disconnected, suggests the possibility of a connection with organic growth. But as yet they have not been studied minutely. The thickness, all told, is about 50 feet.

2. Strata of dolomite gradually becoming tough and cherty, and weathering with deeply pitted surfaces. Thickness in places 40 feet. These contain cherty (fossiliferous?) nodules, small, weathering "in relief;" above which, in sections removed from the old shore line, are often

3. Thinly laminated, tough, cherty dolomites, white to dull grey, or chalky, sometimes with interstratified beds of chert, from one foot to three feet in thickness. Maximum thickness not above 25 feet.

4. Massive chert beds, averaging about ten feet or less, overlaid by

5. Fossiliferous strata of varying thickness and difficult of interpretation. The best judgment the writer can offer is that a set of essentially cherty beds, now largely decomposed, and represented by fragmental surface deposits, *apparently in situ* for the most part, originally made up a considerable part of the Silurian system. At present the total thickness of this cap is probably 50 to 100 feet, although it would be difficult to accept this statement without a knowledge born of actual day by day experience over many square miles of territory. The strata represented by this vast aggregation of debris appear to have been of the following kinds, beginning below:

5a. Dolomitic, light-colored siliceous rocks containing abundant remains of *Stromatopora sp.?*, or of one form or more of Bryozoa.

5b. Much thicker cherty strata, carrying perhaps some dolomite, but now represented by masses of cauliflower or sponge-like ramifications of chert and drusy quartz. For want of better terms I have given these the distinctive working titles of "spongy chert" and "spongy quartz." The exact relations of the two and each to a third form, a compact fossiliferous chert, are as yet unknown. In fact the whole problem relating to the debris awaits a solution which I hope to be able to work out the coming season. To the casual observer the surface capping of the highest Silurian would, no doubt, suggest the idea of a drift deposit. And there are facts which go to support the hypothesis of transportation to a moderate distance. The chief argument of this nature rests upon the truth that, upon the southern border of the debris area, the fragements commonly rest upon strata much lower than those of an age directly antecedent to themselves. There may, perhaps, also be a thinning of the "float" towards the south, and possibly a predominance of the material of the higher strata in that direction. But without special investigation upon these points, a correct estimate of their importance can not be made. Granting these premises, however, it is not to be gainsaid that the whole San Saba section is less complete, thinner, and more deficient in the higher beds than is the case farther north. It is also true that no instance has yet been observed of the mingling of the different kinds of debris in one surface exposure. Wherever such occurrences have been noted there is always evidence of strictly local transportation. More than this, rare outcrops of the actual undecomposed strata in question have been encountered, and they always sustain the same relations, one to another, as those existing among the debris layers. The shattered condition of these fragmental deposits, as compared with the massive structure of the supposed original

strata, is not easy to explain from the study of them alone; but the excessive Post-Silurian dynamism is abundantly manifested wherever a view of the subjacent rocks can be had.

The fossils of the Deep Creek division are extremely numerous in some localities and almost abesent from others. The nodules referred to in No. 2 of the section suggest an organic origin more by their form than by their texture or markings, although there is the semblance of pores upon the surface occasionally. The *Stromatopora?* beds and some of the associated strata contain enormous quantities of a peculiar marking which needs more study than has yet been possible. They seem to belong among the sponges, although this opinion may not be taken as authoritative at present. Some of the strata of a different character are almost certainly sponges, but the writer has not had opportunity to study them thoroughly. Associated with these are forms not the best for determining doubtful paleontological questions, as they are largely the internal casts of Gasteropods. *Straparollus sanctisabæ*, Rœm. (sp.), a smaller *Straparollus*, *Platyostoma?*, *Holopea* (sp. ind.), and a doubtful *Helicotoma*, with what appear to be Annelid borings, are abundant in the "spongy chert." In lower strata several *Orthoceratites* are common. I am unable from lack of literature to determine these accurately, but one resembles *Orthoceras imbricatum*, Sowerby; another is near *O. multicameratum*, Emmons; and a third may perhaps be an undescribed form. This last is short conical, with septa in number between the other species named, and the siphuncle is eccentric, narrowing conically from the body cavity backward. If it prove to be new I propose the name *Orthoceras sansabensis*.

TAXONOMY OF THE SYSTEM.

The classification of the Silurian terranes as arranged in the preceding pages is not wholly satisfactory, although it is the best tentative scheme which can now be framed. In any use which may be made of it, our present inability to explain the exact relations of the Post-Hoover divisions should be borne in mind. There is at least a little suspicion that a part or all of the San Saba Series may be entitled to rank as a separate (Niagaran) system. Here is another unsolved problem which we go afield to study in 1890. The schedule below recapitulates what has already been given in detail.

Group (Era).	System (Period).	Series (Epoch).	Division.	Subdivision.	Beds.	Life.
III. PALEOZOIC.	5. SILURIAN.	2. SAN SABA.	b. *Deep Creek*		"Spongy chert" and "spongy quartz."	*Straparollus sancti-sabae.* *Holopea.* *Helicotoma.* *Annelids.* *Platyostoma.*
					Dolomitic siliceous rocks.	*Bryozoa.* *Stromatopora.*
					Massive chert. Thinly laminated tough cherty dolomites. Fine-grained siliceous dolomites.	*Orthoceratites.*
			a. *Hinton.*		Slabby sponge bed.	*Stromatocerium concentrica.*
					Sandy calcareous shale or slabby dolomites.	
					Fossiliferous horizon.	*Stromatocerium rugosum.*
					Calcareous shaly beds.	
					Crystalline dolomites.	*Maclurea crenulata.* *Favosites.*
					Mottled or "birdseye" limestone. Siliceous limestone, or semi-conglomerate.	
		1. LEON.	c. *Hoover.*		Fine-grained gritty crystalline limestones.	
					Thin slabby fossiliferous limestone—Burnet Marble.	*Gasteropods.* *Maclurea.* *Eocystites.* *Crinoids.*
			b. *Wyo.*		Dark fucoidal limestone.	*Bythotrephis.*
					Brown weathering dolomites and brown shaly magnesian limestones.	
			a. *Beaver.*	2. Bluff.	Siliceous magnesian limestones.	
				1. Cavern.	Sandy shaly dolomite.	

IRRUPTIONS DURING AND SUCCEEDING THE SILURIAN PERIOD.

The problems connected with the dynamic history of the Silurian are not as difficult to solve as some of the earlier complications, and yet there are a few points which still remain doubtful, on account of more recent uplifts and because of unfilled gaps in the record. There are several localities in which the Silurian system presents structural features very difficult to explain upon any other hypothesis than that of upthrow or downthrow of the strata along the courses of the Post-Texan and Post-Fernandan orographic movements—the north and northwest trends, respectively. The lower portion of Katemcy Creek, in McCulloch County, the headwaters of Cold and Little Llano creeks, in Llano County, and the Colorado River along much of the eastern boundary of Llano County, are all bordered upon the east by abrupt cliffs of Silurian strata which extend southward as promontories, or baylike prolongations, sharply outlined upon the west by meridianal fault lines. In the southwest, along the upper portion of James River, in Mason County, and in the northwest, along the San Saba River, as well as over intermediate territory on Bluff and Little Bluff creeks and elsewhere, a similar manifestation of the northwest trend is apparent in Silurian strata. It would seem that these movements ceased before the deposition of the San Saba series, and it may be that they can all be referred to slips along the earlier uplifts, although some of the facts seem to require the solution suggested above.

But there is another series of breaks which certainly represent a subsequent dynamic event. These trend very uniformly in the course north 25 degrees east,* and so far as my observations go they are not characteristic of any terranes of later age than the Silurian.

Invariably this trend has broken all the others which have been regarded as earlier in this report, and they are always broken by those to be hereinafter classed as later trends. Within the area now covered by Silurian strata the results of this Post-Silurian uplift are manifested by faults and changes of dip, but very seldom has erosion brought to view the igneous agents. It is probable that a comparison of such exposures (of which none are now certainly known) with outcrops of the same magma in the much denuded inner area will give us the means of determining conclusively whether the Silurian strata ever extended over the latter district. At present the evidence, such as it is, favors a contrary verdict. There are two belts in which the peculiar phenomena of the Post-Silurian uplift are plainly exhibited over limited areas. One of these is in the north 25 degrees east trend, north of Packsaddle Mountain, on Honey Creek and the Llano River in Llano County; the

*North 16 degrees east, *magnetic;* variation, 9 degrees 15 minutes east; *corrected*, north 25 degrees 15 minutes east.

other follows the same course along the valley of another Honey Creek in Mason County, six miles west of Mason City. The former locality is the one observed, in part, by Mr. Walcott, and the one which forms the foundation for his mistaken reference of all the Central Texas granites to a Pre-Potsdam age.* In both these outcrops there are coarsely crystalline granites entombing masses of schists of a character similar to the adjacent country rock. Mr. Walcott was the first to report this fact, but he failed to observe the true relations of this granite to the other strata, its wholly different character from all other granites of the region, and the series of fractures in Packsaddle Mountain corresponding to the trend of this granite eruption.

It is remarkable that these particular masses are the only examples of schist enclosures in the granite of our region. The granite itself is often nearly white or dull grey, and the black schists form nuggets, or pockets, distributed irregularly through the base, but invariably in intimate association, and usually welded into the matrix, if not materially altered at the edges. Often both the schist and the granite are mutually blended into one another at the contact, and the original schist structure is very rarely retained, except in very thick masses. In the smaller inclusions re-crystalization has frequently taken place to such an extent as to leave no evidence of the previous condition, and sometimes the reaction of the enclosed schist upon the granite has been strong enough to alter the mineral composition of the latter in its neighborhood. Occasionally, where there are good exposures of the adjacent schists in the same trend, slips have occurred, leaving wedges of comminuted schists and granite with "slickensides." Over wide tracts the hard granite is covered with a thoroughly decomposed granite 10 to 30 feet thick. There seems good warrant for the belief that the present exposures are due to denudation of superincumbent strata, but it is almost impossible now to determine whether the Silurian system was represented here by any members at the time of the uplift, although there are some facts which seem to make this improbable. Taking into account the extent and character of the breaks, and the structure, texture, and composition of the granite, I am inclined to believe that this Post-Silurian outburst was of the nature of a sudden release of long continued tension along a line which had not exhibited weakness prior to that time. This view is greatly strengthened by the fact that the same trend has a different aspect, more like the earlier uplifts, in places where an intermediate environment exists; thus for instance, a little west of Cold Creek, and elsewhere, the Texan and later strata have been violently thrown into the breaches caused by this irruption. In other cases, where the capping has certainly extended to the Cambrian strata, these have

* *Op. cit.* American Journal of Science, vol. XXVIII, 1884, p. 431.

been shattered and baked or glazed only at the edges of the clefts. Wherever the Silurian strata, especially the later members, have certainly covered the magma the breaks are like those which would be produced by sudden snappings, and the subjacent strata in such cases have not been broken in the same manner as in the cases previously cited. In the valley of Honey Creek, Mason County, south of the Menard road, there are huge bowlders of the granite once covered by alluvium, but now exposed by stream erosion; and southwest of this, between Honey Creek and Little Bluff Creek, north of the Junction City road, a large area is occupied by blocks and hills of the same rocks. These occurrences and the immense deposits of white sand over much of the area make it very probable that the granitic extrusion from the earlier strata rose to a greater height than the protrusion of the same magma beneath the Silurian strata. Such a condition of affairs is compatible with the hypothesis here advanced, if not really essential to its support.

The importance of this feature will be appreciated when the later granites are considered.

We have still to inquire what cause or set of causes could have been responsible for the elevation of the southern border of our district after the Hoover deposition and prior to the San Saba Epoch. From the observations of Mr. Jermy upon the Pedernales River, in Blanco and Gillespie counties, and from incidental notes sent in from time to time by different observers, it is thought probable that a very extensive land area existed southward after the Hoover Epoch until long after the beginning of the Cretaceous Period. Perhaps there will be found in that direction some further clew to orographic movements which faded out in our area; meanwhile, we can only report the result as an oscillation involving subsidence northward and elevation southward. But extensive discussion on the subject at this time would be premature, because much remains to be done in collecting facts for the study of just such questions.

6. THE NIAGARAN (UPPER SILURIAN) SYSTEM (*Absent?*).

There is abundant evidence that the sea retreated along the northern coast before the sedimentation of the next period, for no Niagaran deposits have been found anywhere in Central Texas, unless we are wrong in accrediting the San Saba series to the Silurian. The uplift which we have assigned to Post-Silurian times may have been more effective in folding the strata northward, and indeed there is some little ground for such assertion. Mr. Cummins, of this survey, informs me that his observations strongly support this view as regards later shore lines in that quarter. There must, then, have been a very large area of dry land during the period of accumulation of the Niagaran strata in New York and Canada, or else contemporaneous deposits

in this region were of a different character. Until special study has been given to this matter the writer prefers to hold the view taken in this report, chiefly because his notes as yet yield no certain evidence of such relations between the undoubted and the doubtful Silurian as would seem to be required by a different supposition. At the same time the fossils, and above all the structural relations, lend much color to the hypothesis that the San Saba series, or a part of it, is the representative of Post-Silurian (Niagaran) deposition. More facts bearing upon this point will be collected for the next report.

7. DEVONIAN SYSTEM.

At several points along the northern border of our district the contacts of the Silurian (San Saba series) with overlying beds are different to what has been reported elsewhere, and not what I have observed in other places. Between what Mr. Cummins and Mr. Tarr, as I understand them, assume for the Siluro-Carboniferous contact in the region about the southwest corner of Lampasas County, there is in some sections an important series of strata of but little thickness, but containing fossils closely allied to Devonian types. Neither of these gentlemen has examined the outcrops referred to, but Mr. Cummins states, after seeing my collections, that a very similar rock underlies his so-called Carboniferous near Lampasas; this he included in his Carboniferous section. The writer, being charged with the study of the pre-Carboniferous rocks, has made incursions to the territory of the later sediments only for the purpose of gaining assurance that no gaps remained unfilled, and the possible occurrence of Devonian was not as fully apparent in the field as it has since become by study of the specimens. Special attention will be given to the subject the coming season, but it is possible now to announce the probable verification of Shumard's doubtful discovery in San Saba County, and the extension of the outcrops into Mason and Menard counties, and probably into Burnet and Blanco? counties. As stated by Shumard,* the thickness of this terrane, if it be Devonian, probably does not exceed fifty feet, although this estimate can not be regarded as strictly accurate in the case of a system but little explored.

All that has really been done to date is the discovery of a few localities in which outcrops appear of unusual strata whose position is intermediate as regards the San Saba series below and the known Carboniferous rocks above. But there are grave difficulties in correlating observations which were scattering, confused as they also are by faults and varying contacts, as well as by areal changes in lithologic complexion. Stratigraphically these rocks all belong with the Post-Silurian representatives, for they are unbroken by the

* Transactions Academy of Science, St. Louis, vol. I, 1860, p. 673.

characteristic Silurian fault course (north 25 degrees east), while the Post-Paleozoic uplifts have affected them in common with the higher beds. Paleontologically, the generic types are, perhaps, a little more near the Niagaran than the Carboniferous, although the specific forms are commonly Upper Devonian, and the composition of the beds is usually nearer that of the higher system. Still, these generalizations do not always apply, and it may be that further discovery will even enable us to construct an important transition system; for, in the northeastern part of Menard County, near the old Pegleg Crossing of the San Saba River, south side, specimens of *Dictyonema fenestratum*, Hall, *Loxonema*, and *Favosites* were found in chert much like certain strata of the San Saba series, and the Devonian (if it be such) near Marble Falls, in Burnet County, resembles the neighboring Silurian, carrying also a Lower Devonian fauna in part.

The provisional reference of this little known system to the Devonian is based upon the occurrence of the following fossils: *Dictyonema fenestratum*, Hall, *Aneimites*, sp. ind., *Psilophyton*, sp. ind., *Nœggerathia?* (or *Rhacophyllum?*), *Taonurus* (*Spirophyton*) *caudagalli*, Vanuxem, *Aulopora serpuloides?*, Winchell, *Cyathophyllum*, *Favosites*, sp. ind., *Centronella*, sp. ind., *Aviculopecten duplicatus*, Hall, *Discina seneca?*, Hall, *Bellerophon*, *Holopea*, sp. ind., *Loxonema solidum*, Hall, *Dalmanites œgeria*, Hall, *Phillipsia*, etc.

THE POST-PALEOZOIC UPLIFTS.

Much of the most interesting geology of our district is connected with events of later date than those we have been discussing. While it is not in the province of the writer to make detailed observations in Post-Devonian territory, it happens that no observer in that field in Texas can completely understand the dynamic history of his district without a knowledge of what is revealed within our area. It is therefore very important to report here such facts as have been collected bearing upon the later upheavals. In the foregoing dissertation we have noticed all the classes of granite in Central Texas, save two. Those which have not been mentioned occupy different territory from the Pre-Niagaran uplifts. Leaving the details of Post-Devonian history to be treated by those who have charge of that geology, it is proper to state what are essential features of our district. The conclusions now to be given are partly verified by the observations of Messrs. Cummins and Tarr in the Carboniferous area northward, and of Mr. Hill in the Cretaceous region upon the north and east, as I understand them. Within the core of the Central Texas region, especially in the district hachured upon the progress map by vertical lines, the later uplifts are more extensive than the outbursts at the close of the Silurian. Excepting the secondary northwest trend of that epoch, concerning which the collected evidence lacks precision,

the results are comparatively slight in the way of upturning of the strata, but the two disturbances since the Paleozoic Era have left enduring monuments in the shape of highly tilted rocks. Such slight unconformities as I have observed among the marginal Post-Silurian deposits, aside from the Cretaceous, are wholly due to overlap, and this statement is, I believe, confirmed by the reports of Messrs. Dumble, Tarr, and Cummins, who have given the subject more careful study in the field. There is no warrant, therefore, for referring either of the later upheavals to a time earlier than the close of the Carboniferous period.

A. THE PRE-CRETACEOUS MOVEMENT.

In the outer area of the Carboniferous, as well as in the earlier rocks, there are numerous fractures and faults trending almost due east and west.* Somewhat similar breaks may also occur in parts of the Cretaceous, but a different explanation must be sought for these, because it is demonstrable that comparatively few of the Carboniferous joints extend upward into the later deposits. In the region occupied by the crystallines and the more ancient sediments the manifestation of this latitudinal uplift is extensive and expressive. We do not yet know all its geography, but it is very significant that the most important structural results in our district were confined to the drainage of the Llano River and Big Sandy Creek. The igneous action was wholly south of the Llano River, so far as can be judged from the observations, unless some provisional Archæan west of Mason, on the Menard road, shall prove to belong to this category. A very stubborn problem is presented in this locality, and I may not have solved it correctly, although some very accurate topographic and geologic work has been done upon it. The probability is that every one of the seven or eight trends of uplift is included in the structure, although only three were clearly recognized in studying the outcrops.

Not far south of this the combinations are different, and as is usual where very comprehensive sections are exposed, there is liability to err in interpreting the structure unless the key has been worked out in less complicated areas. Without the knowledge of the meaning of each trend which has since been gained, it is hardly probable that any one could unravel the intricate network. It is very possible that the Post-Paleozoic upheaval followed the old Burnetan trend more closely in some places than in others, in which case a very good acquaintance with the textural habit of each of the two granites will be necessary in order to distinguish them. The fact remains, however, that the Post-Silurian granite is actually cut through in places by dikes of the material

*North 80 degrees east, *magnetic;* declination, 9 degrees 15 minutes east; ***corrected***, north 89 degrees 15 minutes east.

here referred to a later age, and the question of the relative age of this and the associated rocks is not now involved. The details of this Post-Carboniferous dynamic history must largely be worked out by one familiar with what we have been studying here. It is therefore appropriate for us to inquire into the nature of the problems which still remain to be worked out; for it has been manifestly impossible to give attention to more than the salient features in the time heretofore at our disposal. One of the best fields for the investigation is the extremely rugged area of the Riley Mountains, whose relief has been erroneously recorded upon all previous maps. A little experience in that region has well shown the absolute necessity for doing good topographic work there as a basis for geologic study.

In the northern end of that ridge, at the source of Honey Creek, the Silurian upon a high plateau, abuts against an outer rim of Cambrian rocks along an east-west fault. The strike of the Hoover beds is there in line with the Post-Silurian uplift, but farther south and east, upon the south side of Honey Creek Cove, the faults and strikes are mainly parallel with the Post-Paleozoic disturbance, and the latitudinal trend is beautifully shown by the highly tilted strata, not dipping in one direction, as Mr. Walcott has remarked, "from 10 degrees at the north end of the ridge to 40 degrees at the south end," but varying in strike through faults which give such an appearance upon cursory examination. This upheaval is more or less evident over all the country in line with it, wherever the rocks are adapted to show it; but its modes of expression are various. It will be many years before the details of some of the structure are worked out. A few points of interest have been noted, and these are all we can now present.

From the mouth of Hamilton Creek, Burnet County, and perhaps farther east up the Colorado River to the mouth of Big Sandy Creek, and up that stream to its source, thence on across country in the same course, as far as the Cretaceous escarpment upon the west in Kimble County, the continuation of this orographic movement may be readily traced. In this distance of eighty miles, and over a tract of thirty-five miles on either side of this line, the only known exposure of Carboniferous rocks is this limited one in the Riley Mountains, which has been faulted, downthrown, tilted, and denuded, and it exhibits none of the earlier trends.

About three miles east from this exposure stands Packsaddle Mountain, scored, fissured, and eroded, about as diverse in its structure and as different from the Riley Mountain types as could well be, and yet epitomizing, in effect, the same dynamic events, with those of earlier date as well.

In Mason County, on the divide between Honey and Little Bluff creeks, south of the Mason and Junction City road, Fernandan, Texan, Cambrian and Silurian strata are jumbled by three or four of the dynamic movements,

including the Post-Paleozoic, in such manner as to almost literally leave not one stone among them which has not been overturned.

IRRUPTIVES ACCOMPANYING THE EAST-WEST UPLIFT.

The enormous masses of valuable granite now known in Texas as the Capitol Granites, from their conspicuous and successful use in the State Capitol at Austin, have been generally regarded by the public as restricted to the Marble Falls quarries in Burnet County. On the other hand, most geologists who have entered this field have been disposed to throw all the granitic rocks of Central Texas into one and the same class with these. We have conclusively shown in these pages that neither view is correct, but it has not been a simple matter to determine how to classify them. Having already eliminated so many, it may seem a small thing to decide whether such huge mounds as Granite Mountain, in Burnet County, and Enchanted Rock, in Llano and Gillespie counties, belong to one or other of the last two irruptions. But the writer has had great difficulties in deciding the question, notwithstanding the careful manner in which observations have been made in both localities and in the intervening country. The chief reasons for announcing his belief in the Pre-Cretaceous age of these granites are: (1) That they lie within the belt of greatest activity of this uplift; (2) that the general "pose" corresponds more nearly to the east-west than to any other of the dynamic trends of the region; and (3) the Cretaceous beds lie unconformably upon the granite in parts of Gillespie County.

Mr. R. T. Hill is the only geologist who has previously expressed a similar opinion as to the age of the Capitol granite near Marble Falls. In his paper giving "A Portion of the Geologic Story of the Colorado River of Texas," he remarks:

A few miles east of Marble Falls * * * the Carboniferous shales begin to show much disturbance in the shape of faults, joints, and excessive dip. The underlying limestones also show this by extensive metamorphism as well as by folding, until finally a peculiar topographic feature known as Shinbone Ridge is reached, two miles northwest of the village. This is caused by the lowest or encrinital limestone strata of the Carboniferous having been thrust up almost vertically by the great granite mass which is exposed here, and extends nearly ten miles due west to Sand Mountain.

I have ascertained beyond a doubt, by hundreds of instrumental observations, that the trend of north 50 degrees east, in which these "Carboniferous" rocks (I believe they are Silurian) of the Shinbone are involved, invariably cuts through the Pre-Trinity trend (north 89 degrees east) wherever the two cross; and moreover it is known that the same uplift which brought up these Silurian strata ("Carboniferous" of Hill) also involved a portion of the Cretaceous System, i. e., the Trinity and Fredericksburg divisions, if not more, of the Comanche Series. But Mr. Hill was justified in drawing his

inference from the exposures he saw; for, although my interpretation is based upon evidence accessible also to him upon his trip, it would have been impossible for him to appreciate its import without much detailed study in the surrounding region. He hit upon the correct age of the Capitol granite, but did not get the clew to the structure of the "Shinbone," although he knew and correctly plotted the course of the later uplift to which it belongs, and determined the age of the same dynamic action, as elsewhere observed by him. These granites are marked or clad with their own waste in most exposures, but there are some good contacts with strata under which they have protruded. A very good example occurs in Slaughter Mountain west of the pass through which the track goes between Fairland and Granite stations, on the Austin and Northwestern Railroad. I know of no superposition of Carboniferous rocks upon the sediments covering this magma; but wherever the Cretaceous overlies it, directly or otherwise, it seems to have no dip conformity with it, as do the earlier strata when they appear in contact with this granite.

B. THE CRETACEOUS UPLIFT.

There remains one prominent line of upheaval which proves in two ways its title to be designated the youngest orographic trend: (1) It cuts the other trends without itself losing continuity in any exposures, and (2) it involves the Lower Cretaceous Beds as well as the older strata.

The course of the axes of this uplift is nearly north 50 degrees east.* That it has greatly increased the confusion of structure need not be stated, but there are some features of its distribution and of the late topography which tend to simplify problems which might otherwise be made more obscure. In the Cretaceous area, and in less degree upon the Paleozoic fringes of our district, the effects of the northeast upheaval are easily studied, although at times sections may be found in which it is very difficult to explain the present topography upon any theory which seems to agree well with a majority of the facts. I have sometimes been so puzzled by obstinate exposures of this nature that the whole fabric of the geologic history of the region as now outlined has seemed at variance with any possible interpretation of the Cretaceous and later record. But gradually, after months of study and most careful plotting of the observations, some of the facts which appeared most contrary have at last become among the strongest evidence in support of the geognostic scheme promulgated herein.

Mr. Hill has been very positive that the Cretaceous sea covered the whole of the Central Paleozoic area, of which our district is but a part. I am un-

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*North 41 degrees east, *magnetic;* declination, 9 degrees 15 minutes east; *corrected*, north 50 degrees 15 minutes east.

able to agree with him as regards the area familiar to me, which he has not yet visited; but his cogent reasons for adopting this view for the area northward, which he has examined, are not subjects of this discussion. From the best judgment I can make, after the kindly aid of Messrs. Hill, Dumble, Cummins, and Tarr, in view of my own limited observations north of the San Saba River, it would appear that the violent disturbances which have made the Central Mineral Region a veritable piece of "crazy patchwork" expended their energy largely before reaching the valley of the Colorado River upon the north. In our area, prior to the Cretaceous period, there was, as it were, a struggle for the supremacy in orographic expression of the forces acting along meridianal and longitudinal lines. While it is certain that some of the uplifts at least were but small parts of important continental elevations, it ought not to be forgotten that this was practically a centering point for them all, though not necessarily the initial point. On this account, and by reason of the badly broken condition of the strata, the portion of the region which had all along been an area of shallow water or of dry land, was in good shape for elevation, while the surrounding region was being depressed. Mr. Hill has well shown in his writings the fact of this long continued subsidence in Cretaceous times. We have seen how the Central Mineral Region was in earlier times a changing, but permanent bulwark between the inner and outer seas. The latitudinal uplift at the close of the Paleozoic Era left a new topography, and one which went far towards preventing what would otherwise have been a covering of our district by the Cretaceous sea. At the same time the Lower Silurian anticline trending northward (north 25 degrees east) presented a barrier in a part of our district which has never since been submerged.

Reference has been made to the difference of present level between the Silurian (Hoover) beds in Kimble and Gillespie counties and the same geologic horizon in Burnet and San Saba counties. The relations of these beds and the subsequent Silurian and Carboniferous deposition go to show that the Post-Paleozoic, Pre-Cretaceous orographic movement was foreshadowed late in the Silurian period, and culminated at the close of the Carboniferous period, when subsidence ensued.

But as was previously noted, the irruption of the Capitol granite at this juncture was most active over the eastern half of the district and practically over the southeastern quarter. The subsidence in the north and the elevation in the south resulted in the deposition of several hundred feet of Post-Hoover deposits in the former area, none of which are found in the latter, although they do occur in part upon the east.

Now it happens that the summit of the Trinity (Cretaceous) Series upon the southeast at the border of our district is nearly on a level with the base of the

same terrane upon the opposite side of the latest uplift. Upon the northeast the Trinity-Silurian contact is about three hundred feet lower than the base of the Cretaceous at a Silurian contact on the southwestern border.* The Capitol granite in the southeast is in part overlaid by the Cretaceous unconformably, the altitude of the contact being variable, and the basal Cretaceous strata differing accordingly. More than this, upon the north, east, and west there is a thickness of some 300 feet of Trinity sands, which are absent from much of the southern border. Practically over the district between longitude 98 degrees 20 minutes, and from latitude 30 degrees 30 minutes to latitude 31 degrees 10 minutes, *there is not a scrap of Cretaceous*, excepting minute prongs, which may cross these boundaries from the main outlying area. This uncovered tract of 2300 square miles does not represent the whole of the region now bare of Cretaceous, nor all of the region which has not been covered, for there is a long tongue or promontory, running eastward in the central part, the inner end of which has here been taken as the western boundary, whereas large tracts north and south of this extend farther west. The topography, the geologic structure, the dip of the Cretaceous beds, the absence of the lower beds upon the southeast, the littoral character of the sediments, and the relations of the Cretaceous strata to the earlier rocks, each and all indicate that this area was above the sea during Cretaceous times. There is much variety in the basal members of the Trinity Series, and in almost every case the material is locally derived from the subjacent strata. The conglomerates which lie beneath are in contact with almost every bed, in different places, from the earliest granites to the Carboniferous, respectively, and the lithologic character is nearly as changeable. The structure is that of beach deposits of near-by origin, and the old shore line can be approximately traced in many places.

There is, however, a peculiarity which, at first sight, may seem to conflict with the views here expressed. This is the precipitous character of the Cretaceous escarpment in many places, and the present great elevation of the Cretaceous summit along the borders of the interior area at many points. A cursory examination of the Cretaceous alone might readily result in the conviction that this system had once crossed the lower lying territory, although I can not conceive of such a condition in the case in question without the retention of any remnant whatever over so wide an area; for the erosion and faulting have been such as to give opportunity for the preservation of relics of any beds which once covered the tract. But it is wrong to assume that the general level of the Cretaceous is higher than the earlier rocks in the uncovered region. There are plenty of exposures of granites and other rocks of Pre-Cretaceous age which now stand above the average level of the Cretace-

* This Cretaceous base is certainly made up of much higher strata than the lowest Trinity beds.

ous summit, and what is more important, the existence of upthrow faults along the edges of the elevated Cretaceous plateaus is indubitable. These faults clearly exhibit evidence of their formation subsequent to the deposition of the Cretaceous Beds, but they may possibly be breaks of later date than the northeast Cretaceous uplift. It is not the writer's province to determine the exact Cretaceous horizons involved, nor is the evidence for this obtainable without going beyond the district. There is no doubt that the strata from the base of the Trinity Division to the summit of the Fredericksburg Division, inclusive, were brought up by what is here termed the Cretaceous upheaval. Whether the uplift occurred prior to the deposition of the Upper Cretaceous or at the close of that Period is a question for my colleagues to settle by their observations in adjacent fields. It has been necessary for me to discuss the matter thus far in order to explain some very important topography and some granitic outbursts which are part and parcel of my own district. From my more recent observations in the Wichita Mountains, I feel warranted in asserting that the orographic movement here outlined was of Pre-Tertiary date. Further allusion to this point will be made in the discussion of the geology of the Wichita range at the close of this part of the report.

IRRUPTIVES ACCOMPANYING THE NORTHEAST UPLIFT.

The rocks which most clearly represent the Cretaceous movement within the Central Mineral Region are granites of a type different from any previously described in this report. They are usually less massive than the Capitol granites, more granular, but slightly micaceous, and often porphyritic, with coarse crystals of orthoclase scattered through the mass. In a well defined outcrop near the eastern base of Enchanted Rock, in Gillespie County, there is a very interesting infiltration of milky quartz, both amorphous and as crystals of great beauty. This seems to be of subsequent origin to the granite or porphyry base, and the peculiarity is developed locally in such manner as to have caused the eroding agents to leave peaks or hills separated from the generally much denuded areas in which the northeast trend is prevalent. The igneous rocks of this age are much less pronounced in the topography than the earlier Capitol granites, but they may be well studied in the comparatively flat country east of Enchanted Rock, near the head of Crab Apple Creek, and with less ease in the areas adjoining Granite Mountain. Wherever the Cretaceous contacts with these granites can be observed there is always evidence that their upheaval carried those beds with them; that is to say, the Cretaceous strata are bent over the granites and do not lie unconformably upon the latter, as is always the case with the Capitol granites in contact with the Cretaceous.

There is a noticeable lithologic relation between these latest granite-porphy-

ries and the Capitol granites at their junction, where they shade into each other somewhat gradually. All the features of this character are, however, very readily explainable upon the supposition that the material was in part the result of the remelting of the older magma at its edges.

THE POST-CRETACEOUS DEPOSITS.

There are numerous local accumulations of travertine and tufaceous agglomerates, besides alluvial sands and clays, which may be of some geologic importance in future studies of the surface deposits. But at present very few of these can be considered of much moment in the general history of the country, nor are they of economic interest. There can be no doubt of their Post-Cretaceous origin. In the bed of Cold Spring Creek, near Loyal Valley, Mason County, we dug out a large tusk of a mastodon or mammoth, which was imbedded in the conglomerate, and the material of these deposits is always more or less restricted to the debris of adjacent rocks. Nowhere in the Central Mineral Region have any extensive accumulations of this nature been found, which may have represented a widespread terrane of Tertiary or later date, except in a remarkable basin in the Llano River Valley, about ten miles east of Junction City.

RELATIONS OF THE WICHITA MOUNTAINS TO THE CENTRAL PALEOZOIC ERA.

As stated at page 257 of this volume, the results of studies in the Central Mineral Region left at least a possibility that one or other of the upheavals hereinbefore described might have extended its influence to the little known Wichita Mountains. As the key to our district gradually began to assume definite form, and as the work of other members of the survey became explicit, the probability of the existence of some important relations between the two areas grew more evident. The perusal of Marcy's and Shumard's reports,* although these do not give much idea of the structure of the mountains, indicated that a fair knowledge of that district would be very advantageous in the study of our own.

As, in the opinion of the State Geologist, the trip also promised results of great value in their direct bearing upon the geology of the Coal Measures and Permian beds of North Texas, especially in regard to artesian water conditions, Mr. W. F. Cummins and the writer were instructed to make a reconnois-

*Exploration of the Red River of Louisiana in the Year 1852. By Randolph B. Marcy, Captain Fifth Infantry, U. S. A.; assisted by George B. McClellan, Brevet Captain, United States Engineers. With Reports on the Natural History of the Country and Numerous Illustrations. Washington, 1854. (H. R. Exec. Doc., 33d Cong., 1st Session.) Appendix D—Geology, Part II. By George G. Shumard, M. D.

sance of as much of the Wichita Range and outlying hills as was possible in the limited time that could be given to it. This arrangement was made in order that, by the knowledge already acquired by us, each in his own district, we might more rapidly and certainly ascertain the exact relations of the various formations. The results of this very interesting reconnoissance, as they relate to the Central Mineral District, are embodied herein.

We have had no knowledge heretofore of the age of the Wichitas. Mr. Hill remarks:*

"Concerning the latter [i. e., 'the red granites, basalts, porphyrites, and eruptives of the Wichitas'], no more is now known than was expressed as follows by Dr. Edward Hitchcock some years ago." [Here follows a quotation from pages 146, 147, of Marcy's Report.]

Mr. Hill, in the article quoted,† has given a general statement based in part upon his own observations at a distance, but excepting this, I know of no other allusions in print to the geology of the Wichita Mountains.

Dr. Hitchcock wrote in 1853 a portion of Appendix D to Marcy's report, being "Notes Upon the Specimens of Rocks and Minerals Collected." As he was not a member of the expedition and never visited the Wichitas, the conclusions drawn were necessarily of little importance.

Dr. Shumard, in his own itinerary, gives very little more than a running description of special occurrences of "granite, quartz, and greenstone porphyry," so far as the mountains themselves are concerned.

The impressions gained from the reading of the papers quoted above were about as follows:

(1) That the Wichita Mountains are chiefly granitic, but that irruptives of basic character occur in parts of the region.

(2) That the Post-Carboniferous uplift (Ouachita orographic system of Hill) is represented by a considerable portion of the range, especially eastward.

(3) That unexplored portions of the chain might be found to be of Archæan age.

The last conclusion, in the writer's mind, was based very largely upon the belief that the Central Mineral tract is the key to a wide region upon all sides of it; but the statements made to me by Messrs. Cummins and Hill, who had examined intermediate territory, in addition to my own acquaintance with some of the complicated geology of Arkansas, had much to do with confirming this opinion.

Before proceeding to the discussion proper, it is only fair to quote from Dr. Edward Hitchcock's paper, already referred to, the following generaliza-

*American Geologist, vol. V, p. 73. February, 1890.

†Classification and Origin of the Chief Geographic Features of the Texas Region. By Robt. T. Hill. American Geologist, *loc. cit.*, p. 72 *et seq.*

tion which my recent observations have shown to be correct. He remarks:*

Taking all the facts into the account, I can not but feel that there is reason to presume that volcanic agency has been active in that region more recently than the trap dykes.

Of this more in due time. The route selected took us across the Permian plain northwestward from Henrietta, Texas, by the most direct road to Fort Sill, Indian Territory. Crossing Red River by the ferry below the mouth of the Big Wichita, our course lay along the valley of the East Fork of Cache Creek. Along this line no evidences of any rocks except the Permian sandstones and overlying red clays were seen until reaching a point fifteen miles south of Fort Sill, where fragments of Silurian limestone and a porphyrytic rock appear in the drift. Back of this, at the stage stand about twenty-six miles from Fort Sill, there is an exposure of false-bedded Permian sandstone, apparently dipping south 16 degrees. This is the first indication of an east-west strike which was observed. Black sand occurs in the wash at the southern limit of the drift, and this becomes very abundant nearer the mountains. It is fine grained, crystalline *magnetite*, and probably also *ilmenite*.

About one mile southeast of Fort Sill one of the hills has been cut down upon two sides, and much rock has been taken from the quarry for use in building at the post. This affords a fair section of Silurian limestone very similar to that above mentioned as "float." The horizon is nearly that of the typical section on Cold Creek, Llano County, the fossils being somewhat abundant, but chiefly fucoids and non-characteristic markings. It is exceedingly interesting to find here the same master-joints as in the Central Texas area. The dip is 11 degrees, south 65 degrees east, locally, but the east-west (Post-Carboniferous) trend is well pronounced. The Silurian break of north 25 degrees east is very prominent.

At the southeastern portion of the Wichita range, near Fort Sill, the trappean ridge referred to by Marcy and Shumard presents a marked topographic and geologic feature.† It was evidently not understood by these explorers, and in fact it would be next to impossible to work out the Wichita structure in detail without some such historical key as is furnished by the stratigraphy of the Central Texas Region.

Upon Marcy's Itinerary Map some of this portion of the mountains is marked as "Trap Bluffs," and Shumard's diary has the following entries:

July 17.—Many of the mountains presented a marked difference in character and composition from any that had been previously observed; instead of displaying a rough and

*Marcy's Report, p. 147.

†For these important elevations, extending from the target grounds at Fort Sill westward to the main Wichita range, near Mount Sheridan, I propose the name of "Carlton Mountains," in honor of Colonel Carlton, the present commandant at Fort Sill.

broken exterior, they were more or less rounded, and exhibited a gradual slope to the prairie level, while the granitic structure almost entirely disappeared, its place being occupied by fine porphyry of a reddish color.

July 18.—* * * We arrived at Cache Creek. * * * From the water's edge rose abruptly a long line of smooth perpendicular cliffs, varying in height from 300 to 400 feet, and having in some places a slight columnar structure. * * * Upon examination they were found to be composed mostly of fine porphyry of a reddish color, which was traversed by parallel and nearly perpendicular veins of cellular quartz, varying in thickness from two to three feet.

July 19.—About one mile below our present encampment I came to the termination of the cliffs. A short distance below this I observed a nearly horizontal stratum of coarsely laminated sandstone, fifty feet thick, and including in its composition fragments of igneous rock of the same character as that composing the cliffs, the intermediate space being occupied by red clay, which as before appeared to underlie the sandstone.

These statements, and the view and section given in Marcy's report, describe fairly the situation in the southeastern portion of the Wichita Range. The sandstone referred to as overlying the Permian red clays is what Mr. Cummins calls the Fort Sill Series, and our observations make me think it may be Tertiary. It is persistent along the southern base of the Wichitas for many miles westward, and in most places it is overlaid by thick deposits of Quaternary gravels and boulders of local origin.

The porphyry outcrop of Carlton Mountains strikes in a general way east and west, and a close examination of its structure shows that its eruptive line was probably in the path of the great Post-Carboniferous uplift. This trend is discernible in almost every part of the Wichita Mountain System in the form of joints, and, in every case thus far observed, it breaks all other joint-courses except that trending northeast. This is in exact accordance with the facts in Central Texas.

The texture and the columnar structure of the igneous mass, its peculiar topography, and the mode of deposition, as well as the subsequent erosion, all point to a volcanic origin. The greatest development was off to the west, near where the ridge seems to merge into the main chain southwest of Mount Scott, and here, as in a portion of the eastern end, there is all the structure and resulting topography of an ancient crater. The slopes and semi-stratification give the appearance of lava flows, and this feature is a very common characteristic of the Wichita rocks of different ages.

North of these lava hills, which include the Palisades of Cache Creek above Fort Sill, there is a ridge, or a long series of irregularly disposed peaks, which forms the backbone or the real geologic axis of the Wichita chain. Mount Scott and its eastern neighbor, for which I here propose the name Mount Cummins, as well as other peaks still further east and a multitude of knobs and peaks extending many miles westward, all belong to this nucleal trend.

The geologic course is north 75 degrees west, the very counterpart of our Texas Burnetan core; and wherever I have crossed it or examined it, all along the belt for seventy-five miles, it tells the same tale in its composition and its broken joints, as we have already read in Burnet and Llano counties. Shumard saw these records, although he could not explain them, nor could any one else without the knowledge which comes from the study of a pivotal region like our own. He says:

At a distance they appeared to be smooth, but upon a nearer approach their surfaces were found to be quite rough, and presenting the appearance of loose rock thrown confusedly together. In many places the granite was observed occupying its original position, and was variously traversed by joints and master-joints, which, intersecting each other at right angles, gave to the mass somewhat of a cuboidal structure.

Had Mr. Shumard observed accurately the courses of these joints he would have discovered that in the nucleal ridge, which is practically the water divide, and which Marcy's maps do not well depict, there are represented every one of the strikes which the writer has worked out and dated in Central Texas. And, moreover, this earliest Burnetan strike is everywhere broken by the other trends, in both regions alike.

The Burnetan rocks of the Wichita Mountains are most like some of the more readily disintegrating kinds in the neighborhood of Lockhart Mountain, in Llano County, but the successive uplifts in the Wichita Region have been rather volcanic than plutonic, and thus these relics have become hardened and much more resistant to erosion than their Texas relatives. For this reason, as Shumard has observed, the mountains in the former region often appear like huge piles of massive boulders.

It is a noteworthy fact that there are really very few real granites in the Wichita Mountains. The rocks which have been so called are chiefly porphyries, which may be styled binary granites by courtesy in some of the more ancient types. Mica is extremely rare—I would say it is practically absent, unless it occur in that portion of the range west of the North Fork of Red River, in Greer County, known as the Headquarters Mountains. This small area at the northwestern end of the system I was unable to visit, but it appears to be a continuation of the nucleal Burnetan Ridge.

As we go west, along the base of the Wichitas, two or three prominent spurs run out southward into the plain, which seem at first sight to be mere prolongations of the volcanic ridge of Post-Carboniferous age, but upon nearer approach they are found to be tilted outcrops of the Silurian limestones, of horizons near that at the Fort Sill quarry. These expose a thickness of 150 feet, including a section of the Siliceous limestone extending from below the *Maclurea* Beds to the gritty crystalline marbles of the Cold Creek section. The general dip is 14 degrees south, but in the middle of the most eastern

exposure there is a belt of higher beds, endyked as it were in a nearly vertical dip with a northeast strike, breaking across the strikes of the earlier uplifts. This trend of the Cretaceous upheaval is again visible in the form of joints and special porphyry and quartz dykes, further northeast in the Palisades upon Cache Creek, near Fort Sill.

Upon the far north side of the Wichita range, some sixty miles north northwest of Fort Sill, and perhaps forty miles northeast of Navajoe Town (Greer County) there is a very similar but more comprehensive exposure of the Silurian beds, with the reverse dip of 16 degrees north, and broken escarpments of the same character are visible along the flank of the range eastward. In the outcrops visited by me there is a fine section of 250 feet of the Siliceous limestones extending from below the horizon of the lowest stratum in the Fort Sill quarry to a level equivalent to the summit of the Cold Creek Section of Central Texas. The facies is in all respects identical with the Texas Silurian, except that the beds of the Wichita foothills are more fossiliferous, containing corals, *Brachiopods*, etc., in addition to the meagre fauna of our district.

In all these Silurian cliffs there are beautiful illustrations of sea shore erosion subsequent to their elevation. The Fort Sill Beds run up horizontally to the base of the escarpment and intrude within the irregular bays, which have been cut into it by the waves of the Tertiary? sea in which they were formed. Even in the crater-like basins, high up in the mountains themselves, lacustrine deposits of great thickness have been accumulated, and everywhere the Tertiary and Quaternary sediments have deeply buried the ancient terranes, so that, with the exception of the Silurian and the outlying Permian, there is not a relic of any Paleozoic or earlier stratum of aqueous origin, or any of the schists. The interpretation of the geologic history of the whole Wichita range consequently hinges upon an accurate acquaintance with the meaning of each orographic movement as tested by the character of the irruptives, chiefly eruptive, which each trend displays. In treating the subject, it is assumed that the details of the geology of the Central Texas complex, as outlined in this report, are sufficient to prove the full value of these axial trends as elements in diagnosis wherever the relative ages can be determined by their intersections. This test is all that is left us in the Wichita chain, except, as stated in the case of the Post-Carboniferous uplift, which has involved the Permian Beds in one or two places where they are now uncovered.

The Burnetan axis of the range is the most persistent of all the strikes. If it be true that the Headquarters Mountains, in Greer County, are of this age, as is most probable, the line of peaks, from 200 feet to 1300 feet above the plains at their bases, extends with few extensive gaps for a distance of about 100 miles in a course parallel to the trend of the oldest Archæan rocks of Central Texas.

The great northwest, or Fernandan, trend of our district is also represented in the Wichita Mountains, but in a way which suggests obscured deposits or outbursts of readily denudable material along the mid-course of the chain. West of the point where the Carlton Mountains seem to be stopped by the Burnetan axis of the Wichitas, about twelve miles from Fort Sill on the Navajoe road, there is a broad dyke, or spur, of granitic porphyry not unlike some of the Fernandan irruptives of Central Texas. This is badly broken by joints of the later trends, but the northwest strike is discernible and the general course of the rugged outcrop is maintained for a number of miles. This line of low peaks forms a prominent topographic and geologic landmark not heretofore recognized at its true value. Strictly speaking, it is not a part of the main Wichita range, but a subordinate uplift, checked in its progress by the older axis, as in the case of the much more modern Carlton Mountains. In honor of the chief of the Comanches, whose range is in this neighborhood, the name of Quanah Mountains is proposed for this sub-range.

There are suspicions that certain gaps in the Burnetan axis, at intervals along the chain, have been caused by this later Archæan upheaval. The evidence is often obscured by the Post-Paleozoic sediments, but the present disposition of the compound axial ridges of the Wichita System is such as to frequently cause one to travel northwest to cross the chain through the gaps from the south to the north side. At the intersection of the Burnetan and Fernandan trends there are topographic features in the shape of peaks and passes which are of a distinctive type. West of this for twenty miles the Burnetan axis presents a determined front to the south, as if free from break by important orographic movements, although the joints of the later trends are usually discernible, and a special expression of the northeast course is evident in certain places, besides an interesting development of the Post-Silurian uplift.

The Texan, or north-south, trend is characterized by what is probably the type of Dr. Shumard's "greenstone porphyry." It is a green basic porphyry of coarsely crystalline texture, which is referred to by Dr. Hitchcock at page 146 of Marcy's report. This is associated with a complex rock of similar character, studded with little patches of *magnetite*, and the whole set probably occupies a belt fifteen miles in width, although this is now largely covered by Tertiary and Quaternary deposits. Along its western border, however, it has resisted denudation, and now forms a well marked mountain chain independent of the Wichita-Burnetan axis. Some portions of these outlying ridges can not be so easily explained, and there is reason to believe that an expression of the Ouachita uplift, or east-west trend, is in some way represented. To elucidate these points in detail, such accurate topographic work as we have done in the Central Texas area will be absolutely necessary. I suggest the name Dumble

Range for this rugged row of basic hills, as a token of esteem for my friend and chief, the State Geologist of Texas. A very prominent landmark for many miles at the eastern border of the greenstone, at its intersection with the axial Burnetan strike of the main range, and which seems also to be crossed by the east-west strike of porphyry, is most fittingly denominated Branner's Peak, as a compliment to Dr. J. C. Branner, the State Geologist of Arkansas, an area in which these three trends (approximately) are also well exhibited. This eminence stands like a beacon upon the outer wall. towering alone above its neighbors, which are all of earlier origin. A similar peak, the highest point in the Dumble Range, I would respectfully dedicate by name to Mr. Robert T. Hill, my colleague, as a slight memento of his brilliant career as a working geologist in the vast regions adjoining the Wichita Mountains in Texas, Arkansas, and Indian Territory. Hill's Peak is likewise near the meeting point of the Ouachita and Cretaceous uplifts, and thus it is fitly chosen to honor one who has ably worked in those fields.

It should have been stated that the Texan outcrop in the Wichitas is exactly in line with the main exposures in Llano and Mason counties.

The Silurian trend, north 25 degrees east, is not absent either from the Wichita Mountain System. Admirably is the parallel with our district carried out, even to the two features of striking interest, viz.: (1) the occurrence of schist enclosures in granitic rocks, and (2) the repetition of the Texan and Fernandan strikes in joint-courses.

The granite here is somewhat more porphyritic, and the inclusions are at times altered to blotches of *actinolite* and other basic minerals with a coarsely crystalline texture. But there are different portions of the exposures in which the whole appearance is very decidedly similar to our Honey Creek outcrops in Llano and Mason counties.

The confirmation of the repeated or continued action of orographic movements into Silurian times which had begun much earlier is well brought out in the western part of the Wichitas, where the relations of the joints can often be studied to better advantage than in Central Texas. Beginning, so far as my observations go, at a point about eight miles east of Branner's Peak, where the schist-including granites outcrop, the Silurian trend is very prominent in the joints of the inner or northern system of elevations. In the neighborhood of Branner's Peak there are what we may style boulder peaks of tough granitoid porphyry, which seem to belong to the Burnetan axis in part, but which are also posed about little elevated flats of lacustrine origin in such a manner as to suggest a crater of ancient date. The great gap in the mountains west of this, and the continuation of this same topography off to the south-southwest in an undoubted Silurian uplift, leads me to regard this as an important geologic feature of Silurian type modifying a

Burnetan volcanic focus. Branner's Peak is almost certainly of later origin. The Silurian expression in the southwest, along the valley of West Otter Creek, is a beautiful exponent of the great geanticlinal of Post-Silurian date. No sedimentary beds have been observed as involved in this uplift, but the west branch of Otter Creek flows through an anticlinal ridge of the granitoid porphyry. The trend of this uplift is indicated well in the relief, and nearly all the maps give the facts fairly, although few of them are good for the Wichita Mountains as a whole.*

The sketch map of the region which is given on the Section Sheet accompanying this Report gives such a representation as will enable any one to locate the peaks to which names have been given herein.

To the series of knobs which lie along West Otter Creek Valley, east and north of the North Fork of Red River, opposite the Navajoe Mountains, I have given the name Blanche Mountains, as a tribute to my wife.

The Blanche range, if prolonged in its strike, would cross Texas west of the Central Mineral Region; and Mr. Dumble informs me that there are indications of such a structure in that area, which will receive close attention later.

The Navajoe Mountains, an isolated but elevated ridge upon the west bank of the North Fork of Red River, in Greer County, represent the crossing of severals of the uplifts, being hardened erosion relics similar to some of the remnants in Llano County.

The Post-Carboniferous, or Ouachita, uplift has already been described. The east-west trend is prevalent everywhere throughout the range. Carlton range has no exact counterpart, so far as I have determined, but there are ridges of dolerytic material and dykes of basic character for the most part, which certainly belong to this system. These occur, as stated, near Branner's Peak, in the Dumble range, especially near Hill's Peak, and in places along the northern edge of the Wichita chain.†

It seems probable that Shumard has confounded in his term "greenstone porphyry" two distinct types of lava, one being the Post-Texan outburst of dolerytic rock laden with *magnetite*, and the associated basic rocks passing near

*The latest maps of the United States War Department give the topography very well in some details, and the compilation made for the Land Office map of Texas shows even the Burnetan, Fernandan, Silurian, and Carboniferous uplifts as nearly as the actual topography will admit. The imperfections in this last map are chiefly in the shape of extras which do not occur in nature, and omissions which have been strangely made since the time of Marcy's reconnoissance.

†I have not seen much of the northern side of these mountains between Mount Scott and the head of the East Fork of Cache Creek, but I very much doubt the existence of certain ranges put down there upon recent maps, as they were not visible from any of the peaks ascended by Professor Cummins or the writer.

the base of Branner's Peak, at the divide between West Cache Creek and East Otter Creek; the other including the tough dark gray material of the Dumble range, which is also visible as a dyke cutting through Branner's Peak. Some of this resembles the Little Rock *syenite* in a general way, but this may be only superficial.

Some veins of quartz of the east-west trend have been observed near the Dumble range and elsewhere.

The latest uplift of the north 50 degrees east trend is clearly illustrated by joints which break all the others. In places between the crossings of the earlier outbursts, the Burnetan rocks have been so riddled by this dynamic movement as to present the appearance of loose rock piles, and some of the same ancient outcrops which now peep through the thick Tertiary and Quarternary deposits southward are even arranged in lines corresponding to this latest upheaval. The only typical rock of this uplift, here clearly shown to Pre-Tertiary (if the Fort Sill Beds be Tertiary), is a trachytic red lava, nowhere occurring in great quantities, but chiefly existing as dykes and low hills in the upper valley of Otter Creek.

There are numerous minor relations of an intimate character which bind together the two regions we are discussing, which have evidently been companions in development through the eons of geologic time; but enough has been given to prove that from the earliest Archæan to the close of the Paleozoic their history has been practically the same, although different in degree of igneous activity.

PART II.

ECONOMIC GEOLOGY.

The practical man desires a knowledge of the useful minerals and other natural resources, and he, therefore, often fails to appreciate the necessity for such determinations as have been laboriously worked out for the first part of this Report. But experience has clearly shown that haphazard methods of development are not only ruinous to individuals and corporations engaged in mining, but also detrimental to the legitimate industrial growth of any region. Little as it may be realized by those who have suffered from ill-advised speculation in mining property, and undesirable as the revelation may be to those who live by preying upon the credulity of investors, it is certainly true that there are no isolated cases of marvelous subterranean wealth. If a bonanza in gold, silver, copper, lead, iron, or manganese exists anywhere in Central Texas, it is because certain causes have acted to produce it; and if one such occurrence be known, others of the same kind probably exist in the same region. Still, it does not follow that the discovery by accident of one ore body necessitates a similar method for acquiring knowledge of others. Nothing is now more firmly established than the close relations of geologic structure and mineral deposition. Every competent mining engineer is a structural geologist, or he is wofully unfitted for his profession, however well trained he may be in other very necessary directions. The really practical miner is often the best judge of the proper means of attacking a special problem in excavation, provided that it requires no knowledge beyond the range of his own experience. But whenever any person, of whatever training and experience, assumes to pass an opinion upon values after simple inspection, without such knowledge of the structure and of the chemical composition as can come only from varied experience and thorough tests, he is arrogating to himself powers beyond the capacity of any human being.

No industry can be built upon such a foundation. Whatever may be the future of our district, its development will depend upon its resources as they are, not as they are estimated by any individual, although correct statements of fact will aid materially in attracting attention from capitalists. Unfounded hopes and guesses of inexperienced persons, if converted into cash, may produce a temporary artificial excitement, which will certainly result in eventual disaster. The money which has already been honestly expended in the Central Mineral Region by well-meaning enthusiasts, often without competent advice, would have sufficed to determine the value of the resources of the tract

if it had all been understandingly applied. The amount actually expended in unnecessary work in one investigation would have given a fair knowledge of the economic value of a vast area, had it been used in a different manner. That this is not idle talk, but hard business sense, is proved by the fact that the writer has already been able in several instances to predict accurately the results of explorations in advance of the work, simply from his familiarity with the geologic structure, as outlined in the first part of this Report.

Having, it is believed, given such a statement of the geologic history as will enable interested parties to determine from personal observations what conditions exist in given localitities, it will be the object of this part of the Report to treat the subject from the economic standpoint. For this purpose main headings, grouping together the resources of each class, will be used, the individual su' stances being arranged alphabetically under the different heads.

I. PRECIOUS METALS.

The Central Mineral Region has not taken a position among the producers of the precious metals, and there are now no mines for which any claim is made that marketable gold or silver ore can be taken in profitable quantity.

Nevertheless, there have been numerous workings in various districts, and several parties are still at work upon what they seem to regard as fair "prospects." There can be no doubt that specimens and even small working lots of gold and silver ores have been taken from certain localities, and the geological structure and the nature of the rocks in some districts are at least not indicative of the absence of these metals. But this is far from saying that such ores are abundant or workable with profit. All the facts known to the writer are embodied in the special report on each metal below.

1. GOLD.

There are several possible sources of gold in this region, and much care has therefore been taken to secure fair tests of the different materials. Wherever there has been reason to suspect the presence of this metal, and in many cases where its absence has been almost certain, samples have been taken and assays of the different kinds have been freely made.

The rocks which would be most liable to carry gold are:

1. The various dykes, veins, and masses of quartz which lie in the courses of the several uplifts.

2. The veinstones of different character which fill numerous fissures, especially those bearing north, northwest, and between north and northeast.

3. The streaks and pockets of *pyrite* and other metallic minerals which

often occur among the older rocks, but much less commonly in the later trends.

The assays made by Messrs. Herndon and Magnenat of material collected by myself do not give much promise of profit. The material selected covers the ground well, and it is hardly probable that extensive prospecting will seriously alter conclusions based upon these samples, for they represent all the types which have been detected in the whole region.

In Table I these are shown in connection with the other assays.

It is very probable, as occasionally reported, that higher specimen assays have been obtained, and it would no doubt be possible for prospectors to discover rare pockets, and possibly some better indications than any here reported, but the chances are all against the finding of any auriferous deposits of workable size. The only mining operations which were systematically carried on in the region in 1889, with gold as the object of search, consisted of the sinking of a shaft on Silver Mine Creek, southeast of Enchanted Rock, in Gillespie County. Here the thin streaks of ore, in contorted schists and quartz seams, are chiefly very fine-grained, brassy *pyrite*, with some solid, massive *pyrite* partly altered to *hematite* and *limonite*. There are also, at different depths in the shaft, micaceous schists with spots of oxidized mineral, including also some patches of quartz, *pyrite* being distributed meagerly through the mass. With these occur talcose and weakly graphitic pyritous schists. The mechanical structure, or the crevices, preparatory to the occurrence of a mineral vein are here, but there has not been the regularity nor the subsequent action necessary for the accumulation of such a deposit. The shaft, if continued in its present vertical course, will encounter different terranes and different trends, perhaps, but it is likely to continue mainly in the Archæan. There is a possibility that deeper working may strike similar schists to those in the earlier trends in the Babyhead District, but gold would probably not be abundant even in those.

Thus far, the only district which has given us any returns in gold is the area about the headwaters of Little Llano Creek and Babyhead Creek, in Llano County. Here the gold is almost invariably associated with silver-bearing or copper-bearing minerals, and it is therefore to be regarded as a slight additional inducement to the mining of these metals, rather than as a probable independent source of revenue.

It has been claimed that the enormous alluvial deposits of Big Sandy Creek contain enough gold to give respectable "colors" in the pan, but there has not been any profitable working of these sands. I have occasionally panned deposits of this character in different parts of the district without any results of value, and as the quartz of the whole contributing area is mainly barren, the prospects for future discovery of auriferous tracts is very unfa-

vorable. Perhaps the worst of all places to search for gold is in the veins of red and yellow oxides which occur in faults in the Silurian limestones, as on Hinton Creek, Bluff Creek and at Camp San Saba and elsewhere. These iron deposits have been thoroughly tested, and they contain no other metal. Similar veins in the schists and gneisses, as near Long Mountain, sometimes have rare metals in the matrix, but gold is not known to exist there.

It is true that all possible chances have not been weighed by the Geological Survey, but the whole matter will be most thoroughly investigated before the subject is dropped, and if the final result be any different from this preliminary verdict it will not escape the attention of the writer.

2. SILVER.

It is very difficult to arrive at anything like a satisfactory conclusion regarding the probabilities of silver-mining. As is shown in Table I, seventeen of our assays give traces and six samples have yielded from three ounces to 107.8 ounces of silver to the ton. Without exception, the real returns are from ores of the Babyhead District, including the area from the head of Little Llano Creek westward to the head of Pecan Creek. This fact enables us to form some idea of the best conditions in our region for the accumulation of silver ores. The Babyhead District is one of the tracts in which the Burnetan and Fernandan strata (Archæan) are best exposed, and in addition to this, the greater part has apparently not been greatly disturbed by more recent upheavals. This, it would seem, has left the fissures permanently continuous, and accordingly there has been a much more uniform infiltration than in other sections, where successive disturbances have obliterated possible prior accumulations and closed the channels of deposition. If this idea be correct, we shall find areas of like character the best places in which to prospect for similar ores. There are few such tracts, however, within the territory now uncovered by the Paleozoic rocks. This little district is almost unparalleled even in this region of unique structures. The nearest approach to it is, perhaps, in an irregular area with Bodie Peak and Fly Gap as markers, although limited patches extending along the drainage of Big Sandy Creek for the most part may be other examples. The "traces" given in assays recorded in Table I are mostly from exposures more or less closely connected with the last mentioned district. It is noteworthy that traces of lead are present in nearly all the samples from that tract.* We are not yet prepared to speak understandingly of the special causes which have produced the silver ores, nor of the source of the material of the veins. Enough tests

*All the material marked (J) in the tables was collected by Mr. G. Jermy, and I have no notes concerning the mode of occurrence or other features, although I have worked to some extent over the same field in a small part of Gillespie County.

have been made to show that in all probability no profitable returns can be expected from any except the least disturbed districts, but the facts can not be clearly interpreted without a better knowledge of the veins than has yet been obtained. No very large bodies of silver ore have been encountered in any of the workings. There is encouragement certainly in the quality of the mineral taken from some of the mines, but the explorations should be conducted upon a larger scale than has heretofore been possible with the means at the disposal of the landholders. The ore must be won by shafts, and pumping facilities will be required at an early stage. By judicious management, giving attention to the geologic structure and expending money chiefly in one place, there is at least a reasonable prospect that a fair return may be realized upon wise investments in this region.

Not a few shafts have been sunk, some of them to a depth of more than 100 feet; but the mistake was made very often of excavating much larger pits than were justified without better knowledge of the deposits. In some cases, incompetent overseers did a large amount of wild work, such as the sinking of several deep shafts side by side, at intervals of less than a dozen feet, running trenches through wide veins of barren quartz already well exposed by nature to greater depths in the immediate vicinity, and similar costly and useless operations. The lack of pumps and the necessary appliances for deep work has compelled the abandonment of nearly all mineral enterprises in our region; but when capital, advised by experienced engineers who know where *not* to work, shall have entered this field prepared for extensive developments, a thorough test of the resources can be made with relatively low costs. An advantage over many districts similarly placed is the occurrence of valuable ores of copper in the same locality.

The ores which have given the highest returns in silver come from several shafts, known locally as the "Mexican Diggings," on a branch of Babyhead Creek, south of Babyhead Mountain, in Llano County. The mineral is *tetrahedrite* (gray copper) in white vein quartz, with *galena* and *chalcopyrite* irregularly distributed. The sample (No. 11, Table I) was my own; not an average of the vein, but made by "cobbing" the samples to a grade such as could readily be prepared by hand assorting at the mine.

Specimen assays would run higher, as this contained much quartz. It is, however, next to impossible to say in what quantity the ore can be mined from present development, as the shafts are flooded and the ore-streak is but a few inches in width at the surface. The associated rocks are Burnetan or Fernandan types, which abound in the vicinity. Outcrops of the quartz are abundant. At present I am unable to say whether the veins are uniform or "pockety."

The Mexicans, who have periodically worked here, have erected two fur-

naces of simple type, besides a crude sluice for washing (concentrating) the ore, and a small arrastre for grinding it. Assay No. 12, in Table I, is lead matte from the reverberatory, and No. 10 is concentrated ore from the same place. I have no means of knowing positively that the ore came from this place, but it agrees well in character with what occurs *in place* in the neighboring veins.

The occurrence of silver ores, as stated, proves that the conditions for such deposition were present in the Babyhead District, and it is not improbable that other places of the kind may be found. But prospectors should give most attention to localities in which these same conditions prevail. There are no exposures elsewhere as favorably placed, although it may be that erosion has uncovered similar limited areas. The next most promising fields, perhaps, are the country east of Mason, in Mason County, and along the upper valley of Comanche Creek, and the lower valley of Beaver Creek (Mason County). Other suitable districts may possibly occur in Gillespie County and northward on tributaries of the Big Sandy; but explorations have not thus far been successful in that tract.

The occurrence of *galena* in the Burnet County Beaver Creek District opens a possibility for silver production there. As far as now known, there is no probability of any occurrence of the precious metals in any other mineral in that area.

Referring to assay No. 4, in Table I, for particulars, and to the title "Lead" for a description of the environment, further mention here is unnecessary.

II. BASE METALS.

Under this head, for our purpose, we may class copper, lead, zinc, and tin, these being the only metals of the group, excepting iron and manganese, which present indications give any hope of discovering in the region.

1. COPPER.

The district from which the greater part of the specimens of copper ore have come is almost identical with the silver tract. The occurrence of copper, however, is more extended than the known deposits of silver-bearing minerals. A cause of this may be, perhaps, the greater readiness of the copper minerals to oxidize. This idea is, in a measure, supportea by the fact that such copper ores as are known outside of the silver vein courses are almost wholly carbonates. Such as least has been my own experience with these ores. The new element of distribution is the north-south trend, and apparently a basic irruptive? of Post-Texan age is the exciting cause; for it is where meridianal dykes of such material transect the Burnetan or Fernandan trends that stains of *malachite* and *azurite* are found in the Texan rocks. The

junction of these two or three ancient trends, especially where the dips of the different systems are unequal, will make mining difficult, as it will necessitate a thorough knowledge of the rocks and of the local strikes and dips of the Burnetan, Fernandan, and Texan systems. Besides this, the slips, faults, and contortions make a complicated underground structure, which not only requires much study to follow it properly, but it is also liable to cut out the ore bodies or make infiltration impossible. Still, any vein which shows well at surface has probable continuity in depth, or it would not have been brought to light. The deposits which can certainly be made out to be associated with igneous rocks of the north-south trend are most probably the easiest to follow, because that is a late uplift in the afterward little disturbed copper belt.

But it is not probable that the richest ores lie in this trend at the surface; on the contrary the assays made for this Report give the best record to the most ancient course—north 75 degrees west, the one in which the silver ores chiefly occur.

A. THE BABYHEAD DISTRICT.

The Babyhead District is the best copper region now known in Central Texas. The ores at surface are largely carbonates, both *azurite* and *malachite*, the latter predominating. *Tetrahedrite* (fahlerz) is more or less common, occasionally, but not always, carrying a notable amount of silver. *Chalcopyrite* is sometimes present, but usually not in much abundance. None of the diggings have gone below the zone of surface action, and as many of them have not followed the veins, it is difficult to form an opinion as to economic values. Results of assays of my samples are given in Table I, with localities. Below are brief descriptions of the principal workings, beginning upon the east at Little Llano Creek.

HOUSTON AND TEXAS CENTRAL RAILROAD DIGGINGS.

On railroad land (section No. 3, survey 1239) near the mouth of Yoakum Creek, north side, there is a peculiar ridge of hornblende rock, or of schists with a hornblendic belt or belts running through them. The appearance at the diggings near the summit of the ridge is that the north 75 degrees west (Burnetan) trend is the course of the copper-bearing band, but the strike of the schists is apparently northwest (north 36 degrees west—northwest, *magnetic*). A semblance of a north trend is also visible, but there is little evidence of a strike in that course. The rock is stained with *malachite*, which also partly saturates porous masses. Some parts contain a little *epidote*, and *magnetite* is abundant in places in fine grains. According to the proportions of the iron ore, the specific gravity of the gangue varies from 3.277 to 3.978. (Table I, No. 4.)

M'GEHEE DIGGINGS, HEAD OF LITTLE LLANO CREEK.

In the upper valley of Little Llano Creek, where it flows nearly east, work has been done on a tough garnet rock, carrying patches of fine-grained *bornite*. This is probably Burnetan material, trending north 75 degrees west, and thus it agrees with most of the ore deposits of the region, although excavation has not entirely followed this course. The gangue is massive, but its environment is very similar to that of the crystalline garnet in the same trend on Clear Creek, Burnet County. *Fibrolite* accompanies the garnet in both places. Some of the ore here (Llano County) is saccharoidal in appearance, causing a glistening which makes it seem to contain more *bornite* than is really present. Two assays of the product of this shaft are reported in Table I.

M'GEHEE SHAFT, YOAKUM CREEK.

About one mile east of Babyhead Postoffice, near the head of Yoakum Hollow, Capt. McGehee, the pioneer of the Babyhead District, has sunk another shaft which seems originally to have been in ore upon a vein or deposit coursing in the Burnetan trend. The exploration, as in other places, has been pushed more in a north-south direction, and the ore body has been missed in the deeper workings. This excavation illustrates the difficulty of development in the region and the necessity of gaining a practical knowledge of the geologic structure before planning work. Not far east of the locality, a northward bearing fault has further complicated matters, and the mixture of trends below surface, here as often elsewhere, makes a dyke or an upturned stratum more prominent than the ore body. In this case the gangue is largely a granitic rock, impregnated with *malachite*. Assay No. 6, from this locality, was selected ore and does not represent an average product, although it may serve to indicate the quality of the mineral streak when assorted closely.

M'GEHEE SHAFTS, WOLF CREEK.

Two deep shafts not far apart, connected (I am told) by a drift now under water, were sunk by Capt. McGehee on a hill between Wolf and Babyhead creeks. The situation is very similar here to what has been described at the Mexican shafts on Babyhead Creek, but there is more copper strain in the quartz. This property was not in condition for detailed inspection much below the surface, at the time of my visit. There is some appearance of ore at the outcrop, and small crystals of *chalcopyrite*, with some *tetrahedrite*, occur sparingly. That is all that can be predicated of the vein above the present water level.

The Burnetan (older Archæan) rocks come out well in their characteristic

trend in a wide belt, extending across the upper part of the drainage area of Wolf Creek and Pecan Creek in Llano County. In this tract which is merely the westward extension of the Babyhead District, there is even a stronger expression of the ancient uplifts, although it can not be said that subsequent breaks are lacking. A large amount of prospecting has been done here, and although all has been abandoned for the nonce, the owners claim they are not discouraged by what they discovered. There certainly can be no doubt of the occurrence here, as in the main Babyhead District, of valuable copper ores, sometimes carrying silver, but determinations of quantity are almost impossible from the indications presented by the flooded workings. The mineral streaks which bear the richest ore are apparently thin. but some of the workings show fair-sized pockets or "swells." Much labor has been expended in places which yield no signs of metalliferous ore, and there are abundant outcrops of barren white quartz following the same course as the veins. Judging from the strike (north 75 degrees west) and the persistence of certain physical features, it is very probable that two, possibly three, mineral belts cross practically the whole of the Babyhead District from Little Llano Creek to the divide between Pecan and Magill creeks. Between these, or perhaps forming part of the same belts, are barren areas which give no signs of anything but quartz or schists.

Between the Miller and the Hubbard mines, which are on Pecan Creek waters, there is a broad outcrop of white quartz, which shows most plainly eastward between Wolf and Pecan creeks, in the shape of high knolls and dykes. In many respects these resemble the outcrops in the same trends and of the same geologic age at Barringer Hill, on the Colorado River, but the minerals of that locality are not duplicated here, so far as now known. Towards the northern edge of this belt the schists and granites appear, impregnated with the copper minerals. Another similar tract runs south of the barren? quartz. A description of some of the old workings on Wolf and Pecan creeks will serve to make the conclusions understood, which are given beyond.

HOUSTON MINING COMPANY DIGGINGS, WOLF CREEK.

In the northern ore belt above mentioned a number of test openings have been made, some of which on Wolf Creek show well enough to encourage further exploration. In one place, where Mr. Streeruwitz, of this Survey, formerly worked, there is an abundant staining or impregnation of the granitic rock in a streak several feet in width, the enclosed mineral being light green *malachite* (copper carbonate). It would seem impossible for such a body of this material to occur under such conditions as it exhibits without the existence of important ore bodies in the neighborhood. There is a kind

of vein structure at this point, and the comparatively slight working has made a good showing. The ore, however, appears more solid than it really is. Assays of my samples do not give as high returns in copper as might seem likely from the rich color and apparently great degree of saturation by the carbonate. But, as will be seen by reference to Table I, No. 18, the grade is such as to encourage development if the quantity can be proved adequate.

MILLER MINE, PECAN CREEK.

Farther west and north, upon the west bank of Pecan Creek, the Miller mine was opened in a situation somewhat complicated by faults and broken vein courses. The ores, like those near Babyhead Postoffice, are high grade copper carbonates, with admixtures of silver-bearing minerals. The deposits here have more the character of fissure veins than is the case in some openenings; but it is very difficult to form a rational judgment as to the size or courses of the ore bodies from such examination as one can make in the flooded incline and drifts. A large excavation of irregular shape was made here, as if the confused structure had made it uncertain in what course the ore body lies. This again emphasizes the urgent necessity for a thorough knowledge of the local structural geology upon the part of the worker in this field.

HUBBARD MINE, PECAN CREEK.

The ore belt lying south of the massive quartz exposures is somewhat similar to the one in which the foregoing properties have been worked. The Hubbard mine is the principal excavation, and its output has not been materially different from the products already described, although it and several other shafts to the eastward present features more closely parallel with the McGehee diggings upon the southern belt, between Wolf and Little Llano creeks.

With all the puzzling questions which it has been necessary to solve in order to get a general idea of the occurrences of economic minerals in our region, it has thus far been impossible to give to any one locality that detailed study which would be requisite for the formation of a business opinion as to the probabilities in the only district where any serious attempt at mining has been made. That the record has not been such as to positively prove the possibility of commercial success is very evident in the abandoned shafts, very few of which are now in condition to be critically examined. Upon the other hand, the existence of rich ores over a well defined area, in deposits which partake of the vein character, especially when considered in connection with the geologic history, affords encouragement to the view that a general source of supply is buried somewhere in the region.

As a mining engineer, charged with estimating the resources of Central Texas for public purposes, I have not felt it incumbent upon me to make

such examinations of individual properties as would be demanded of one employed by private parties. It is, therefore, only proper to state here the general conclusion that while pioneer work and crude methods of excavation have not developed a paying mine in the whole region, there is such a showing in a general way as will justify the expenditure of considerable capital in further explorations, provided that it be used with due caution under competent advice and superintendence. Without much preliminary investigation and the most prudent management, success can hardly be anticipated.

The writer has examined fully thirty localities in the Babyhead District in which excavations have been made in search of copper ores, and all of them agree well with one or other of the prominent types already described. The conclusions already given apply with more or less force to all. The prospecting has not been so thorough as it has been extensive.

B. THE KOOCHVILLE DISTRICT.

There is only one other region in which copper prospects have been detected, but the extent of that tract may be considerable, although discovery has thus far been limited to one locality. In Mason County, in the southern part of the German Emigration Society Survey, No. 750, about two miles west of Koochville, there is an exposure in the bed of a little branch of Comanche Creek. These rocks have been leached out at the surface, and yet samples taken from the outcrop in the creek assay high enough to attract attention. (See No 29, Table I.) A very little work was done here a few years ago, but the traces are almost obliterated now. The geologic structure is very much like that at the excavations in the vicinity of Little Llano Creek, excepting that here the north-south trend prevails and the older strikes are deeply buried. The same or similar conditions prevail over a large area adjoining, and it may be that further search will be rewarded. Deep workings in this region may be best. On some accounts there would seem to be greater chance of a continuous vein in situations like this than in the cases already described; but this is reasoning more upon general principles than upon exact knowledge of the local problems which the workings have not yet revealed. The writer hopes to be able to investigate this matter more fully in the season of 1890.

2. LEAD.

We shall have to devote more special attention to the Silurian rocks before the exact relation of any of them to the galena limestone of other regions is made clear. All that can be positively asserted now is that the most promising lead district within the Central Mineral Region is where strata abound of an age not far removed from the horizon of the Missouri galena ores. Aside from the small proportions of lead in some of the veins of the Babyhead Dis-

trict, there are several areas which have been reported as possible producers of the metal. Of these tracts, only one has yet shown good warrant for the hopes of its advocates, although it would seem that this can not monopolize the essential conditions, for there are other very similar exposures.

The Beaver Creek District, in Burnet County, has been explored by shafts which do not extend to a great depth. The situation, geologically, is peculiar, and I have not yet had time to give it the attention it deserves. But nothing is given herein at second-hand, and enough personal observations were made in 1889 to get a clue to the main features. To bring the information as near to date as possible, my efficient aid, Mr. Charles Huppertz, was sent to the district in February, 1890, and such later data as he obtained are embodied herewith.

At the head of Silver Mine Hollow, a branch entering Beaver Creek from the left bank not far above its mouth, there is a granite exposure in contact with the Potsdam strata. The adjoining region is much faulted, and alternations of Cambrian and Silurian beds make up much of the section exposed in the canyon walls of the Beaver Creek drainage basin. Apparently in the fault courses, or part of them, there are veins or dykes, the courses of which are north 25 degrees east, and perhaps east-west and northeast, although the effect of the first named, or Post-Silurian, irruption seems to be most marked. The granites, however, are of both this and the Post-Carboniferous type.

The veins are not quartzose or granitic, but rather sandy and ferruginous, the lead-bearing mineral (*galena*) being scattered through the mass in small crystals. The *galena* is not confined to the veins; in fact, it is more abundant in dark gray to green magnesian limestones, perhaps near the Cambro-Silurian contact. The ore is scattered through the mass of the rock, as if segregated, but it does not occur usually at any great distance from the veins in the limestones. The excavations have chiefly been made in the search for silver, and this has probably prevented the prospecting of the neighboring cavern limestones, which may perhaps really be the sources of supply if they are the equivalents of the galena limestones of Missouri and Wisconsin. The whole subject needs careful examination, which it will receive at the writer's hands as soon as practicable. The hopes for a silver industry based upon these deposits is not promising, for there is nothing but the *galena* to yield that metal, and the assays do not indicate its presence in paying amounts. Assay No. 4, Table I, gives an idea of the present product, such as may be easily obtained in moderate quantity by very simple methods of excavation in the veins and the adjoining limestone. It is very probable that systematic exploration in this region may result in the discovery of large and valuable deposits of *galena*, for the rocks, the mode of occurrence, and the geologic age of the ore beds correspond generally with the conditions existing in Mis-

souri, Illinois, and Wisconsin, where lead has been successfully produced. "Rule of thumb," guess work, and theoretical practice of persons unable to work out geologic structure will, however, damage this district, as in many other instances. What is needed is careful and thoughtful observation by trained eyes, explorations wisely conceived, and plans of development executed under skilled management. It may be many years before the usual process of discovery will determine the value or lack of value of the district, but comparatively little well directed effort under competent guidance would soon settle the question whether lead bonanzas exist in cavities in the limestone. As preliminary, this Survey will undertake to determine the coming season, if possible, the geologic relations of the strata in which the lead has already been found. We know now that the *galena* occurs in beds which lie somewhere between the base of the Potsdam limestone and the Deep Creek Division of the San Saba Series, and it is more than probable that the horizon is very close to that of the Galena Limestone of other States. As in other districts of the Central Mineral Region, perhaps in less degree, the structure is confused by faults and dips of different ages, and therefore no one who is not accustomed to such mining problems can expect to succeed in following the complicated veins or dislocated deposits. The practical difficulties will be great enough for the highest engineering talent, although the key outlined in this Report will enable a good geologist to start understandingly upon the investigation of local details.

West of Lone Grove, between the road to Llano and that to Valley Spring, there is a vast exposure of quartz very similar to that traversing the Babyhead District. In this a very little *galena* and *chalcopyrite* (*copper pyrites*) have been found, but I have been unable to detect any indications of a deposit of ore of any importance there as yet.

While working in the canyon of Bluff Creek, Mason County, Mr. J. H. Caylor brought me some very choice specimens of pure *galena*, larger and better than any which have come under my notice as products of any part of the Central Mineral Region. He afterward guided me to the locality from which he claimed to have taken the ore. The spot is about on the divide between Little Bluff and Honey creeks, eight miles west of Mason, south of the Junction City road. Here the rocks are badly jumbled, several of the ancient trends appearing, and faults and contortions producing a chaotic structure. It is possible that the conditions existing upon Beaver Creek, Burnet County, are repeated here, but there is no certain evidence of this, and, if so, the confusion is much greater, so that it might be a herculean task to develop any ore bodies which may lie in the tangled rocks. In the bluffs south of this point the work would be easier, provided the rocks are the same, which may be the case. The peculiar topography southwestward is

not much different from that on Beaver Creek tributaries, and no prospecting has been done in the region.

The excavation shown by Mr. Caylor did not exhibit a speck of *galena*, and I was unable to find any within a mile or two upon either side. Chemical tests have failed to reveal more than a trace of this metal in any material collected within many miles of it. A large amount of brown *calcite*, having the appearance of *siderite* (iron carbonate), had apparently been taken from the recent excavation. It is very probable that *galena* occurs in small pockets in this, but it is not proper to offer an explanation for what is only hearsay evidence of the occurrence itself. It is at least strange that Mr. Caylor could not show some traces of *galena in situ*, if he found his specimen there; but I am by no means disposed to doubt his word. If such material occur in these rocks a very little further exploration should make it evident, although directions can not well be given now for such investigations, as the rocks lie in various trends. Some one interested in the property ought to dig and blast in the vicinity of this excavation.

TABLE I. GOLD, SILVER, COPPER, LEAD.

Collections by Theo. B. Comstock, unless otherwise noted. Those marked (J), in locality column, were collected by Mr. G. Jermy, Assistant Geologist of this Survey.

No.	Locality.	Material.	Gold, oz. pr ton.	Silver, oz. pr ton.	Copper, per cent.	Lead, per cent.	Remarks.
1*	E. Br. Spring Creek, Burnet County.	Ferruginous......	.....	......	......	......	Vein in mica schist.
2*	E. of Nigger Head Peak, Burnet County.	Quartz with lithomarge (*Carnat*).	.....	.....	......	......	
3*	Br. Peters Creek, Burnet County.	Brittle, reddened quartz.	.....	......	......	......	From schist contact.
4*	Beaver Creek, Burnet County.	*Galena* in limestone.	.....	Traces.	.. ..	45.3	Hand assorted.
5*†	H. & T. C. R. R. land, mouth of Yoakum Creek, Llano County.	Amphibolyte with *malachite*.	.....	.....	2.3	......	Not assorted.
6*†	H. & T. C. R. R. land, Yoakum Creek, Llano County.	Granite charged with *malachite*.	.....	......	3.5	......	One-fourth mile west of No. 5.
7*†	Yoakum Creek, near head (McGehee Shaft).	*Tetrahedrite* and *malachite*.	0.2	12.2	45.6	......	Selected ore.
8*	Head Little Llano Creek, Llano County.	Garnet rock with *bornite*(?)	.....	.... ..	1.3	......	Collected by C. Huppertz.
9*	McGehee diggings, head of Little Llano Creek, Llano County.	....	.....	Trace.	0.6	......	
10*	Mexican diggings, Babyhead Creek, Llano County.	Quartz...... ...	.....	......	......	......	

TABLE I. GOLD, SILVER, COPPER, LEAD—*continued.*

No.	Locality.	Material.	Gold, oz. pr ton.	Silver, oz. pr ton.	Copper, per cent.	Lead, per cent.	Remarks.
11*	Mexican house, Babyhead Creek, Llano County.	*Galena* and slag..	Trace	93.5	...	43.34	Concentrates.
12*†	Babyhead Mountain, in Llano County.	Assorted ore.....	0.2	107.8	6.4	Trace.	
13*	Mexican house, Babyhead Mountain, in Llano County.	Lead matt	...	3.0	......	44.83	
14*	Pecan Creek, Llano County.	*Malachite* and *garnet.*	.....	......	1.0	......	
15*†	Miller Mine, Llano County.	*Malachite*........	.....	......	40.40	......	Trace of zinc.
16*†	Pecan Creek, Llano County.	*Azurite* and *malachite.*	.....	25.00	25.60	......	
17*†	Yoakum Creek, in Llano County.	Granite with *malachite* and *azurite.*	.....	Trace.	4.4	......	
18*†	Pecan Creek, Llano County.	Granite with *malachite.*	Trace	3.5	10.80	Trace.	
19†	Packsaddle Mountain, in Llano County.	Quartz..........	.....	Trace.	......	......	
20*†	Near Packsaddle Mountain, Llano County.	Mineralized quartz	.....	Trace	.....	......	
21*†	Chaney diggings, Llano County.	Pyritous marble..	.....	......	......	......	
22†	Four miles south of Llano, Llano County.	Quartz..........	.....	Trace.	.....	... ..	
23*	Pontotoc, Mason County.	Washings.......	.....	......	......	......	
24*	Pontotoc, Mason County.	Quartz..........	.....	......	......	......	
25†	Near Caylor's diggings, in Mason County.	Segregated *limonite* and *hematite* in limestone.	.....	Trace.	......	......	
26†	Divide between Honey Creek and Little Bluff Creek, in Mason County.	Siliceous dolomitic marble.	.....	Trace.	......	......	Specks of black mineral.
27†	Quarter mile east of Caylor diggings, Mason County.	Dolomyte.........	...	Trace.	......	......	Specks of black mineral.
28†	Caylor diggings, in Mason County.	Blue quartz......	.....	Trace.	......	......	
29*	Caylor diggings, in Mason County.	*Calcite*..........	.....	.....	......	Trace.	Traces of zinc.
30*	German Emigration Survey No. 750, one mile northwest from Koochville, Mason County.	*Malachite* stains in hornblendic rock.	.....	......	1.8	......	
31*†	Nonley Shaft, Gillespie County.	Mica schist, altered	.....	Trace.	......	......	Somewhat pyritiferous.

TABLE I. GOLD, SILVER, COPPER, LEAD—*continued.*

No.	Locality.	Material.	Gold, oz. pr ton.	Silver, oz. pr ton.	Copper, per cent.	Lead, per cent.	Remarks.
32*†	Nonley Shaft, Gillespie County.	Talcose and graphitic schist with *pyrite.*	.....	Trace.	......	......	So-called ore streak.
33*	Head of Crab Apple Creek, southeast of Enchanted Rock, Gillespie County.	*Pyrite,* brassy in schist.	.....	......	......	......	Copper test by T. B. C.
34†	North Br. Sandy Creek, Riley Mountains, in Llano County.	Quartz	.....	Trace.	......	.....	
35*†	Sandy Shaft, Gillespie County(J).	*Graphite* and *pyrite.*	.....	......	......	......	
36*†	Sandy Shaft, Gillespie County(J).	*Graphite, pyrite...*	.....	Trace.	......	......	
37*†	Sandy Shaft, Gillespie County(J).	*Graphite* and *pyrite.*	.....	......	......	......	
38*†	Sandy Shaft, Gillespie County(J).	Altered *pyrite.* ..	.....	......	......	......	
39*†	Sandy Shaft, Gillespie County(J).	*Graphite* and *pyrite.*	.....	......	......	......	
40*†	Sandy Shaft, Gillespie County(J).	*Graphite* and *pyrite.*	.....	......	......	......	
41*†	Sandy Shaft, Gillespie County(J).	Altered *pyrite....*	.....	......	......	......	
42*†	Near Iron Creek, Gillespie Co.(J).	*Galena.........*	.....	Trace.	......	Trace.	
43*†	Near Iron Creek, Gillespie Co.(J).	*Galena.........*	.....	Trace.	......	Trace.	
44*†	Hickory Creek, Gillespie Co.(J).	*Pyrites.........*	.....	Trace.	......	......	
45*†	Pedernales River, Gillespie Co.(J).	*Galena.........*	.....	Trace	......	Trace.	
46*†	Pedernales River, Gillespie Co.(J).	*Galena.........*	.....	Trace.	......	Trace.	
47*†	Kino Creek, Gillespie County (J).	Altered *pyrite....*	.....	......	......	......	

*Analysis by J. H. Herndon. †Analysis by L. Magnenat.

3. ZINC.

One accustomed to the western ores and to the extensive deposits of zinc-bearing ores in the northern and eastern mining regions can not but be surprised at the sparsity of this metal in Central Texas. Aside from the traces obtained in the *calcite* in Caylor's diggings (described above) there has not been any indication of the presence of zinc in any rock or material in the Central Mineral Region. This is a remarkable fact, and one which must be passed without any explanation. In a tract so large, and with such varied features as this, it is not impossible that I have overlooked occurrences of zinc-bearing minerals, but nothing of the kind has yet been brought to the attention of this Survey in any manner, and no claim has been made, to my knowledge, that any such ores exist in the area covered by this Report.

4. TIN.

The same might be said of tin as of zinc, were it not for claims which have been made of the discovery of the former in two or three separate localities. On this account, and because of the receipt of a very fine crystal of *cassiterite* (tin oxide) from a gentleman who did not seem to know its nature, and who stated that it came from the stream "wash" near the point where he gave it to me, I have taken much pains to search for tin ore. Failing to get reactions for this metal in any of the minerals of my own or my assistants' collections, Mr. Huppertz was specially charged with the examination of the locality referred to above and of the adjoining region, in the hope that more of the same material might be found. But the quest has been fruitless. The area is an extension of the Barringer tract, and one not unlikely to yield tin minerals, if they exist at all in the Central Mineral Region.

Great care has also been exercised to detect tin in the rare minerals of the immediate Barringer district. To this date (May 1, 1890) no evidences of the presence of the metal in any combination have been seen by me anywhere, although I have examined critically more than 8000 specimens collected from various parts of my district. There are areas in Blanco and Gillespie counties which I have not worked over except in the most cursory manner. Of these it is impossible to speak authoritatively at present, but such collections of the Survey as have come under my inspection certainly contain no tin.

III. MANGANESE ORES.

Although manganese occurs in many places as a constituent of limonitic iron ores in veins, and occasionally as jet black, glossy streaks of *braunite* or *manganite* in crevices in special situations, there are only one or two restricted districts which are liable to become producers of manganese ore upon a commercial scale. The Spiller mine, in the mountains, or rather in the foot-hills, south of Fly Gap, has an extended local reputation because of the money expended by its owners in boring with the diamond drill, ostensibly to test the continuity of the deposit in depth. This is really the only known occurrence of such ore upon an extensive scale anywhere in this region; but as there is nothing in its environment to indicate strictly local conditions of accumulation, it is hardly likely that diligent search will be unrewarded by the discovery of similar deposits. In fact, the writer has already traced out several probable companion belts in the neighborhood of the Spiller mine by surface croppings as good as are commonly used as indications in other States. The quartz, which is well exposed west of Schussler's and north of Brown's, about one mile or less northeast of the Spiller mine, is much stained with manganese oxide. The course made out here is north 25 degrees east for the

strike of the broad quartz bands. Prospecting in this locality would be justifiable from the surface indications, but it seems probable that the northwest trend is the one which carries the best ore.

The Spiller mine is really a series of shafts and diamond drill borings near the summit of a ridge of granitic and quartzose rocks, lying about two miles west of south from Fly Gap. The ore is a rather siliceous *psilomelane*, with patches of *pyrolusite*, and more or less black *wad* filling cavities and crevices in the vein, which is three to four feet in width.

The strike of the rocks here is north 36 degrees west—the Fernandan trend—and the ore seems to lie as an interbedded vein The vertical shafts have not followed the ore, which hades off to the southwest, in which direction a number of borings were made with the diamond drill. There is very little development, and one can not, therefore, form a very correct idea of the situation below. Such deposits are liable to be "pockety," but the outcrops of this vein on the surface are somewhat persistent. Streaks of quartz run through the ore rather irregularly, but a little care in blasting and sorting will enable operators to bring the material to a marketable grade in considerable quantity. Below are given analyses of several samples collected by the writer:

	I.*	II.*	III.*	IV.*
Water	....	....	....	3.00
Silica	11.47	46.15	43.10	19.13
Ferric oxide and Alumina	9.00	7.50	18.35	7.63
Lime	3.05	8.90	9.74	0.73
Magnesia	1.31	Trace	Trace	Trace
Phosphoric acid	Trace	Trace	Trace	... ...
Sulphuric acid	Trace	....	....	....
Manganese protoxide	....	....	29.04	....
Manganese sesquioxide	56.63	36.12	......	66.64
Manganese dioxide	....	1.48	Trace	3.06
Total	100.28	100.15	100.23	100.19
Available oxygen	9.20	3.93	... ..	7.31
Metallic Manganese	51.33	26 07	22.48	48.32

*Analyst, L. Magnenat.

Another field which has yielded some manganiferous ores, and which may be worth prospecting for manganese ores, is that portion of the district between Packsaddle Mountain and the Riley Mountains in which the northwest strike is at the surface. The occurrence here of quartz with manganese stain and the similarity of the deposits generally to those in which the manganese ores occur elsewhere, as well as the identity of structure in other particulars, all make it possible that the indications of ore point to much the same conditions of accumulation as those existing at the Spiller mine. These remarks are very general, but they can not well be more explicit until special

investigation can be made of the causes which have produced these ores. There are important differences in the geology of the two regions here mentioned, and it is too early now to decide whether the deposition of manganese minerals has been affected thereby, or whether the similarities may not outweigh the divergences. It is interesting to note that the Fernandan and Silurian strikes occur in both places.

Manganese as an ingredient of limonitic ores is not uncommon in veins of different ages, but perhaps most frequently in those following the more ancient trends. A good illustration of this is given in Table IV, No. 5. In some cases particular streaks are strongly enough charged with the oxide to entitle them to be called ferruginous-manganese ores, rather than manganiferous iron ores. But it is doubtful whether any of these accumulations are important enough to cut any figure in the industrial development of the region.

IV. THE IRON ORES.

In a region of very rugged topography, much broken by faults and deeply eroded, it is not reasonable to expect that exposures of any one group of rocks will occur in all parts alike. It does happen in this case, however, that almost everything within the wide range from Archæan to Recent is somewhere exposed in such manner as to enable its structure to be understood. Thus it is that the history of iron deposits in our district has been pretty closely made out, so that the resources of this kind may be estimated with some degree of accurary.

The three classes of iron ores, viz., the Magnetites, Hematites, and Hydrous Oxides, are all represented, and each has practically a *locus*, or mode of occurrence, of its own. It is best to treat these classes separately.

1. MAGNETITES.

The Magnetites lie in the northwest Archæan trend. They do not appear in their greatest development in all exposures of these rocks, and it may be doubted whether there is actually a continuous bed, or set of beds, forming a definite horizon in the Fernandan System. Some of the outcrops comport as well or better with the idea that they are "lenses" or "bosses" of ore brought to their present condition by local causes. But in many instances it has been found that, while the large masses may be apparently discontinuous across the region, there is usually an indicator of continuity in the shape of a line of ferruginous soil or other land mark; and when the undecomposed hard ore again presents a topographic outline of its own, it is usually found to possess the same character as its representatives in the same trend. This statement may be verified by any one who will take the trouble to note the

positions of the bright red soil belts which are successively crossed in going from Lone Grove to Cold Creek, on the Burnet and Mason road, or in traveling an equivalent stretch of country by almost any other route. It is also a very interesting fact that the derived, or secondary, iron deposits of later date, in the basal Cambrian strata at least, follow roughly the same trend, though in a much less pronounced manner.

The area in which the Fernandan beds prevail as surface rocks may be limited for the present practical purposes by northwest-southeast lines, drawn through Lone Grove Town upon the east and through Enchanted Rock upon the west. This blocks out a district twenty miles wide and extending, perhaps, thirty miles in the direction of the strike. Within this field, however, various structural features have prevented, in many places, the outcropping of the iron-bearing system, so that probably two-thirds of the area is not in condition to yield ore without removing thick deposits of later origin. Assuming that one-third of the territory, in scattered patches, will show the Fernandan Beds at surface or at depths that may be considered workable from an economic standpoint, it must be understood that only a small fraction of the thickness of these strata is iron ore. Keeping in mind also the folded condition of the rocks, it is evident that the chances for mining will be dependent largely upon the character of the erosion, it being premised that the iron bed, if such it be, is not very near the top of the system to which it belongs.

It is the province of this Survey to obtain facts and to draw conclusions concerning the general nature of the ore deposits as dependent upon geologic structure. It is not, as some have imagined, the business of the writer to ascertain and inform every land owner of the value of his property or of its mineral contents. But if any intelligent citizen will apply to individual cases the generalizations in these pages where they fit, and if he will undertake to study his own locality as a minor, but integral, part of one or other of the districts outlined in our natural classifications, he will at least be able to determine whether he can hope to discover iron or other ore upon his land.

The main facts and the conditions in which the magnetic ores are placed are these:

1. Whenever a set of rocks appears such as is described in Part I of this Report under the head of Iron Mountain Series,* there is liable to be a valuable deposit of *magnetite.*. *In prospecting, be sure that you have a set of rocks whose strike is very nearly northwest* (*magnetic*).

2. If, in the same connection, a large amount of red soil occur in comparatively narrow strips, there may be a good ore body at no great depth beneath the decomposed portions. Wide belts, especially along valleys of

*See page 271 of this volume.

streams, are usually not of this class. *To test the matter, dig down to bed rock only, and do not waste labor in excavating rocks which you do not know. Pay out money for competent advice and act upon it. If you or your friends or "practical miners" "have never seen such rocks before," experienced engineers can tell you their values accurately by their tests.*

3. A body of *magnetite* ore having been found, it may be followed by the dipping needle or by prospecting in a northwest or southeast direction. *But when you strike the red sandstone or other rock overlying, the beds with the northwest strike will disappear beneath the others.*

4. Beds trending nearly north-south resemble these somewhat, but they are of later date and the magnetic ores occur beneath them. *You can rarely find the ore bodies by digging in such places unless you have an intimate knowledge of the geology of the country.*

5. There are at least three parallel belts in which it is possible that valuable deposits of *magnetite* may be discovered.

A. THE BABYHEAD BELT.

The most eastern outcrops follow a course represented by a line bearing southeastward, west of Babyhead Postoffice and Lone Grove, and coming out southward very near the Wolf crossing of the Colorado River. This belt is well exposed in the Babyhead Mountains, but is buried beneath the Cambrian strata before reaching the north line of Llano County, which is thus practically the northern limit. The typical strike of the Fernandan System can be traced southeastward nearly to the Colorado River, with some breaks where more recent uplifts or alluvial deposits have cut out or obscured its path; but no workable outcrops of the ore have attracted attention except those in the vicinity of Babyhead. There is every reason to expect good results from prospecting in the tract here outlined, especially in the north half, down to the crossing of Miller Creek. Northward between Lone Grove and Lockhart Mountain, and southward from Lone Grove as far as Miller Creek, the carbonaceous and calcareous strata have not been eroded from above the ore beds, and still farther southward the later granitic masses have largely obliterated the original structure. These geologic features are not as favorable to economic mining as the conditions prevalent north of Lockhart Mountain, because the ore cannot always be found at the surface in the former areas. But the exposures in the Babyhead Mountains are partly due to faults, and it is not improbable that limited districts elsewhere in the belt may present conditions suitable for working.

However, it must be remembered that this field is one in which the Burnetan System is prominent. This means that denudation or lack of deposition over much of the belt has left no chance for discovery of any of the Fer-

nandan rocks, or of their thin edges only. The Magnetite Beds themselves are not here so thick nor so prominent as in some other districts.

B. THE LLANO BELT.

There is an area about five miles in width between Packsaddle Mountain and the Riley Mountains, in which the Fernandan rocks are well exposed where they are not cut out by later uplifts. This belt extends northwest to the Cambro-Silurian escarpment. The rocks are folded here as in the areas on both sides, and several times the succession of the strata is repeated. In all the exposures the typical Fernandan section is exhibited, and there is usually some indication of the presence of iron ores in situations which correspond to the horizon of the Iron Mountain Series. The marbles and graphitic schists cross the Brady road between Pecan Creek and Valley Spring in two places, and ores of value have been detected in a number of places among these outcrops. Over much of the road between Lone Grove and Llano, and between Llano and Valley Spring, there are beds of red hematite sand, which may be the results of the alteration of underlying magnetites. A tract of this kind, not very far from Lone Grove, very probably represents the Babyhead Belt, either in place or as a transported product. Another passes west of Wright Creek, and has been examined by me at several places in its course. Near the mouth of Public Pen Creek, northeast of the Wolf Mountains, between the two roads from Lone Grove leading to Valley Spring and Llano respectively, I have seen good altered surface indications of the *magnetite*, and these also come out in Public Pen Creek not far northwestward, and again in the upper valley of Willow Creek. In the same course, southwestward, this belt crosses the Lone Grove and Llano road, where it exhibits similar features. Still another line of outcrop crosses the Llano River near the lower ford at Llano, and this is again repeated near the upper ford, one mile above Llano, but in these cases the marbles prevail. In all the outcrops of these Llano belts, which are broken at intervals by faults and granitic irruptions, the *magnetite* seems to lie at a considerable depth below the surface, and its products appear at surface now as *hematite* or *limonite*. A marked example of this is visible at the Chaney workings, near the southwest corner of Packsaddle Mountain. Numerous observations have been made which confirm my judgment that the magnetite horizon is a persistent one in the Fernandan system.

C. THE IRON MOUNTAIN BELT.

There are two localities in which the development of the magnetite deposits has been undertaken with some degree of enterprise. In both places very large and valuable masses of this mineral have been exposed. The belt is

most persistent and can be traced for many miles. It has been worked at Iron Mountain and at points south of Llano, while fragments of ore have been collected from the tract at the southeastern base of the Riley Mountains, where the quantity of derived segregations on the surface is also enormous.

THE "IRON MOUNTAIN" OUTCROP.

About one mile and a half north of west from Valley Spring Postoffice, upon the right bank of Johnson Creek, the ground slopes somewhat steeply beyond the old flood plain of the stream, and at the culmination of the hill a small ridge or mound formerly stood out in relief. This was the condition at the date of the writer's first visit, in June, 1889, but by the time it was again examined, in the following August, the excavations since made in the so-called Iron Mountain had changed its appearance, so that now it would be difficult to understand this nomenclature. The course of the iron ore and its probable persistency in the northwest trend was clearly made out when I first examined the locality, and the excavation of numerous pits all over the adjoining space was unnecessary, as has been proved by the results, which fully confirm my original views regarding the strike and character of the mass. The section of the rocks at this point has already been given under the head of the Fernandan System, in Part I of this Report. The quantity of *magnetite* and *hematite* at this outcrop is very great, and the explorations made by a shaft and drift since my last visit have increased the knowledge of its extent. Mr. Chas. Huppertz, who was sent to the spot in February, 1890, thus reports:

> They have sunk the shaft straight down the side of the iron outcrop, going down about fifty feet and then turning across into the "lead" about twenty-two feet. There is also a digging about one hundred yards from the Iron Hill and shaft, and being in a southeast direction from the hill, it is presumed that the "lead" strikes northwest and southeast.

The occurrence of a very high phosphorous *hematite* layer upon one side of this outcrop is peculiar, as almost no phosphorous exists in the average of the ore. A reference to the section given under the head of the Iron Mountain Series, Part I of this Report, will explain the probable cause of this streak.

THE WAKEFIELD TRACT.

In the course of the Iron Mountain Belt prolonged southeastward there are other exposures of the *magnetite*, but erosion has apparently not extended far enough in parts of the line to uncover the ore, while in other places the detrital deposits have obscured the continuation, if it exist, as the writer believes. About three miles south of Llano City considerable prospecting has been done in this and parallel belts. For want of a better name this will be referred to as the Wakefield tract, although the work done by Mr. Wakefield in the region is by no means limited to this area. Here the *magnetites* and

associated rocks and ores of the Fernandan type have been again brought to view in a position adapted to mining, and the situation is very similar to what has been noted concerning the Iron Mountain outcrop. The ore, especially from shaft No. 1, is almost identical with the Iron Mountain product, and there is little to be said of one locality in this preliminary Report which will not apply with equal force to the other, excepting that the topography of the two areas is not the same in detail.

D. THE WESTERN BELT.

West of the Riley Mountains, between that range and the Enchanted Rock, and perhaps over a greater breadth in the northwest, the Fernandan Beds appear occasionally, and in wide exposures in some areas. The outcrops of the *magnetite* are less understood in this belt, because the country is fenced in and not easy to investigate. It is also a tract which has many complications, and one which had to be neglected in part last season for lack of time to work it properly. Still the belt was crossed by us with section lines in four places, and several special reconnoissances were made in other parts; so that a generally correct idea has been obtained of the economic situation. The indications are good for the discovery of important masses of iron ore in the district, but at present I am unable to clearly define the position of the *magnetite* except by analogy with the outcrops of the other belts. Much of this tract is covered by thick deposits of the later sediments (Cambrian, etc.), and granitic irruptions and other complications have made a rather puzzling structure. But there are two or three parallel lines trending northwest across the area in which the hematites are well developed, from which I judge that the magnetites are not very far to seek in certain outcrops.

E. GILLESPIE COUNTY MAGNETITES.

The writer has done practically no work as yet in Gillespie County beyond a rapid reconnoissance, which he is not willing to consider more than an introduction to a knowledge of the geology of that area. But he knows that *magnetite* of excellent quality occurs there in some quantity, in positions which indicate extensions of the mineral belts of Llano County southeastward. In Table II, No. 6, the analysis is given of a fine granular *lodestone*, having very much the appearance of the Iron Mountain hematite streaks. This is the best iron ore yet discovered in the region. It was collected by Mr. G. Jermy, Assistant Geologist.

Table No. II gives results of analyses of magnetites in this district with all necessary details. A perusal of this list (in which only typical ores occurring in quantity are given) will make apparent the richness and purity of this class of iron ore. These are first class bessemer ores, and they must eventually

become an inducement for the growth of a vigorous mining industry in the district of which the town of Llano is now the commercial centre. The distribution of these ores is sufficiently indicated by the localities given in the table.

TABLE II. MAGNETITES.

Localities.

1. Iron Mountain, Llano County.
2. Iron Mountain, Llano County.
3. Iron Mountain, Llano County.
4. Iron Mountain, Llano County.
5. Iron Mountain, Llano County.
6. Gillespie County (J). *Lodestone.*

	Ferric Oxide.	Ferrous Oxide.	Silica.	Alumina.	Lime.	Magnesia.	Phosphoric Acid.	Sulphuric Acid.	Total.	Metallic Iron.
1*	74.14	15.41	3.50	6.25	Trace.	....	1.02	0.24	100.56	63.87
2*	81.31	8.12	4.70	6.17	0.65	Trace.	0.02	Trace.	100.97	63.23
3*	65.40	16.53	5.80	11.07	0.78	Trace.	Trace.	0.18	99.76	58.62
4†	65.70	23.20	4.70	4.44	1.40	....	Trace.	Trace.	99.50	64.02
5†	77.10	16.54	4.65	0.76	Trace.	....	Trace.	.75	99.80	66.82
6*	68.64	26.49	5.10	....	0.01	....	....	....	100.24	68.63

*Analysis by J. H. Herndon. †Analysis by L. Magnenat.

2. HEMATITES.

The analysis of iron ores given in Tables II, III, and IV represent really more classes than are indicated by the arrangement adopted. As explained in the preceding pages, there are real magnetites occupying a definite geologic position, and there are also true hematites, with stratigraphic relations almost as closely restricted, while a variety of the limonites* are distributed according to principles to be explained in another place. In addition to these three classes it might be possible to make up one or two other sets with characters sufficiently distinctive to entitle them to separate consideration. But it is best for the present purpose to group them as in these tables, thus allowing the term *hematite* to assume a commercial rather than a strictly mineralogic significance. This adjustment is not at variance with the modes of occurrence of the ores, which naturally fall under three general heads when considered from this standpoint.

In the Central Mineral Region the true *hematites* occupy a position midway between the *magnetites* and the *limonites*, in age, in composition, and in mode of origin. Some of them have too little ferrous oxide to be fairly rated as *magnetites*, although they are anhydrous and resemble *magnetite* in texture

*A general name of *hydrated iron oxides*, as here used.

and other qualities. A close examination of these will make it clear that they contain a certain amount of disseminated *magnetite*, which fact explains the occurrence of the iron protoxide. Others are slightly hydrated, amorphous, and generally similar to *limonite*, but with the color and streak of *hematite*, and giving its blow-pipe reactions. Careful observation and detailed study of the occurrences of the different varieties prove that this gradation of the *hematites* both ways into the other classes is not merely hypothetical, but that sharp lines are not drawn in the actual outcrops where the different types occur together. The transition is real, not fanciful.

Beds of *hematite* in our district are unusual, excepting where they occur with the *magnetites*, as previously explained. This mineral occurs here under somewhat diverse conditions, but it has not yet been observed in any situation where its relations are such as to imply an independent origin. So far as known it is with us a secondary deposit—a derivative from the subjacent *magnetite*, directly or indirectly. Sometimes it occurs in a way to suggest the reverse alteration from *limonite*, but such cases are comparatively rare. There are also special inclusions in certain veins of quartz, but these are not now under review.

The outcrops of this class of ores along portions of the northern border of the *magnetite* area are chiefly segregations in Cambrian sandstone, occurring as black or blood-red impregnations, varying in quantity from simple coloration and cementation to thin streaks, ramifying seams, and even solid strata of noticeable thickness. In some places erosion has cut off the sandstone in such a manner as to leave low escarpments of the iron-bearing sandstone, and this has given rise to the erroneous idea that there is an east-west strike to these deposits. There is certainly a wide field for inquiry concerning the history of deposition of the *hematites*, but enough has been learned to explain fairly the common methods of occurence. Three different kinds of exposures may be made out as viewed with reference to their modes of origin. To these, for convenience, we may give names as follows: (1) *Altered Magnetites;* (2) *Concretionary Ores;* and (3) *Hematite Sandstones*. Such a classification does not exhaust the variety due to local and special causes, but it gives a sufficiently accurate arrangement for a preliminary discussion.

(1) THE ALTERED MAGNETITES.

A very common experience in our district is the observation by travelers of large amounts of what may be termed "iron float" in pebbles, boulders, and apparent strata. These occur at intervals in various parts of the region, but especially at or near the contact of the red Cambrian sandstones with the Fernandan strata, along the borders of the *magnetite* area previously defined. To the novice there is not much difference in the material at sight, but almost

everybody who has handled the float at a number of separated localities has been led to remark that some of it is very heavy, while other pieces of exactly the same appearance in other places may be of the weight of ordinary rock. This statement is true, except that there is usually a distinction in the appearance of the two qualities which would not escape the attention of a trained metallurgist. The former variety is almost always gray to bluish gray with a sub-metallic lustre, and the latter is never so, although it may be black and glossy, or even show a hackley fracture. Some of this material is also flinty.

Now, if the prospector will take the pains to note carefully the localities in which the heavy metallic float occurs, he will probably find that it comes from places where the Fernandan *magnetites* are buried beneath the Cambrian sandstones. A part of the float, and possibly some of the Cambro-Fernandan contact rocks, may be changed *magnetite*, but when *hematite* occurs in such situations it is almost certainly a product from the alteration of the underlying *magnetites*. Perhaps the largest portion of this kind of material may have been modified since its deposition in its present *locus*. The facts remain that it is now *hematite* of much value, and that the distribution is restricted. The bonanzas of this kind seem to occupy zones following approximately the trends of the *magnetite* belts.

It is difficult to explain their formations, for they are usually compact like vein stones, and many of them contain Cambrian fossils, although none of the impressions are very large.

These border ores are very valuable, and some of them may come into market eventually. The necessity for stripping them of an increasing thickness of the later strata as they are mined farther from the outcrops will retard their development somewhat. At present none of the exposures have been marked, and it is uncertain how much reliance ought to be placed as contributions to the future output of the region. They are probably not very thick themselves, but they may prove invaluable as "indicators" in the search for buried deposits of the Fernandan *magnetites*.

(2) THE CONCRETIONARY HEMATITES (SEGREGATIONS).

Probably the segregated ores have been drawn up from below to some extent. There is an open door here for the student of chemical geology into a study, the threshhold of which I have only been able thus far to cross. As nearly as my observations can be interpreted as yet, the history after the accumulation of the contact *hematites* of the Cambrian (chiefly or wholly Lower? Potsdam) seems to have been about as follows:

1. The deposition of sandstones, highly ferruginous.
2. The segregation of the iron-bearing portion in streaks and veins through the mass of the sandstones, sometimes impoverishing the rock and

rendering it crumbly, but much less commonly than in regions such as Western Arkansas, where this process has acted excessively in carboniferous rocks.

There is a considerable variety in the segregations, and it is not always easy to learn what circumstances have caused these differences, or whether there is any natural order of arrangement of the products. The conviction is strong that the nodular, concretionary, and streaky types are nearer the base than the disseminated, cementing, and friable kinds, but much special study must be given to these points before definite conclusions can be deemed admissible. An interesting hint is given by the assays, some of which, although reacting as *hematites* to blow-pipe and physical tests, are founds by analysis to yield small portions of water.

(3) THE HEMATITE SANDSTONES.

Usually overlying the segregated ores, where these form a distinctive stratigraphic horizon, are strata of sandstone of a peculiarly rich blood-red color, varying much in texture and compactness. Some of them are exactly what some of the red sand soil of the magnetic belts would be if it were re-silted and hardened; other portions are similar, but variegated by laminæ, or partings, of pure white sand, and among them is a remarkable granular *hematite* sandstone, often with the grains not firmly cemented together. This last has often the reactions and physical characters of *beauxite*, but the percentage of water is too small for this mineral.

The chief commercial value of this set of rocks will depend upon their capacity for being washed or "jigged" to free them from the siliceous base. Many of them will be useless for this purpose, and fortunately it is not at all likely that it will be necessary to resort to such methods in this district, owing to the abundant supply of far richer ores, carrying higher percentages of iron, which would readily deceive even experienced metallurgists if judged wholly by appearances.

Table III gives analyses of a fair assortment of the three kinds of *hematite* here described. As previously hinted, there is another class of pure, coarsely crystalline, specular hematites, which have sometimes been mistaken for high grade silver ores. These may appear to a novice like "grey copper," but they are not minutely crystalline, and they exhibit a blood-red streak when scratched by a knife or other hard substance.

These ores occur in white quartz, usually only in such small proportions to the gangue as to make them valueless for use in the iron industry. Occasionally, as in the vicinity of the Kothman Water Gap, east of Fleming Post-office, there are pockets or possibly workable? masses of such ore; but I regard all such cases as indicators of the occurrence of iron in the region

rather than as evidence of local deposits. These manifestations are apparently connected with cross dykes in Burnetan strata wherever we have met them. They are well developed in the region of the Body Mountains, near Fleming, in the King Mountains, and elsewhere, and near the divide between Hooking Hollow and Spring Creek, in Burnet County.

DISTRIBUTION OF THE HEMATITES.

As may be inferred from the foregoing statement, the geographic range of the hematites is much less restricted than the magnetic ore belts; and yet there is such a close relation between the two that we may almost determine the *locus* of one from the discovery of the other, provided that certain stratigraphic conditions are fulfilled in the exposures. But the *hematites* are not all as deeply buried as the *magnetites*, and they belong in large measure to later periods, which in our region are represented by deposits now extending over wide areas. Speaking then of the whole group of *hematites*, it is proper to state that they are chiefly to be sought in the red sandstones of the Cambrian System, and especially at the contacts of these with the earlier terranes as well as in the same situations as the *magnetites*. With much local modification in accordance with principles already outlined, their general distribution outside of the magnetic belts is along the edge of the Central Mineral Region, particularly upon the north, south, and west. In Mason County there is an irregular fringe of the rocks in which these ores often occur elsewhere, and it may be that important outcrops in that section may yet be discovered. Quantities of fine segregations occur in side canyons of the James River valley, and some of the collections from this country seem to indicate the near presence even of the *magnetites*. At Caylor's lead? diggings, near the divide between Honey and Little Bluff creeks, I got No. 12, Table III, which is one of the best of the *hematite* ores of the whole region. The northwest and other trends cross near this point, and it may be that diligent search will develop something of great interest, although the confusion of strata is too great there to hope for continuous deposits of any kind.

TABLE III. HEMATITES.

Localities.

1. Iron Mountain, Llano County.
2. Iron Mountain, Llano County.
3. Iron Mountain, Llano County.
4. Iron Mountain, Llano County.
5. Near Packsaddle Mountain, Llano County.
6. South of Packsaddle Mountain, Llano County.
7. Pontotoc, Mason County.
8. Pontotoc, Mason County.
9. Brady Road, two miles east of Smoothing Iron Mountain, Llano County.

10. Three miles southeast of Camp San Saba, McCulloch County.

11. Twelve and one-half miles from Mason, on road to Camp San Saba, two miles northwest of Katemcy, Mason County.

12. Caylor's diggings, Mason County.

13. West of Christian Schneider's house, near Castell, Llano County.

14. Near Castell, Llano County.

15. North of east of Castell, Llano County.

16. Silver Mine Hollow, Llano County.

17. Iron Creek, Gillespie County.

18. Three miles southeast of Camp San Saba, McCulloch County.

19. Gillespie County.

20. Gillespie County.

21. Gillespie County.

22. Gillespie County.

23. Gillespie County.

24. Gillespie County.

	Ferric Oxide.	Silica.	Alumina.	Lime.	Magnesia.	Phosphoric Acid.	Sulphuric Acid.	Total.	Metallic Iron.
1†[1]	89.70	2.13	....	Trace	Trace	Trace	Trace	100.23	62.79
2*	78.03	3.50	17.11	Trace	....	0.54	0.85	100.09	54.62
3†[1]	79.09	2.65	14.50	3.05	....	......	Trace	100.41	55.36
4*[1]	76.93	5.30	5.90	3.46	Trace	7.16	0.22	100.63	53.85
5†	82.61	9.75	....	1.60	Trace	.....	......	100.10	57.83
6*	77.35	10.20	9.65	0.53	......	Trace	0.24	99.97	54.16
7†[1]	87.2	6.03	....	......	......	Trace	Trace	....	61.04
8*[2]	85.68	12.60	1.12	Trace	Trace	Trace	0.16	100.03	59.98
9*[1 3]	24.73	69.50	2.85	1.48	Trace	0.86	Trace	100.54	17.31
10†[1]	79.47	13.84	4.62	0.55	Trace	Trace	Trace	99.84	55.63
11†[1]	86.58	2.67	....	......	.....	2.21	Trace	....	60.61
12†	88.48	4.11	5.82	0.40	Trace	......	0.43	99.24	61.94
13*[1 4]	44.86	47 88	4.14	Trace	Trace	Trace	......	99.39	31.40
14†[1]	86.22	8.51	2.45	Trace	Trace	Trace	0.12	99.95	60.35
15*[4]	42.07	47.70	6.53	1.24	Trace	Trace	0.24	99.58	29.45
16*[1 4 5 6]	6.18	65.31	12.43	1.42	0.54	0.86	0.41	100.02	4.33
17*[1] (J)	91.4	1.90	1.33(?)	1.73	Trace	.09	.12	100.00	63.98
18*	21.19	46.80	....	......	......	.....	.....	......	......
19*[3] (J)	79.56	10.80	3.04	4.45	0.04	0.26	0.24	99.11	55.69
20*[1] (J)	91.41	1.90	1.33(?)	1.73	Trace	0.09	0.12	100.00	63.99
21*[3] (J)	53.85	27.00	4.15	8.80	0.75	Trace	Trace	99.75	37.70
22*[3] (J)	34.88	54.80	5.32	Trace	0.41	Trace	0.12	100.31	24.42
23*[3] (J)	41.31	36.20	9.09	3.45	1.51	0.24	0.03	100.37	28.92
24* (J)	84.15	8.90	4.25	2.14	Trace	0.70	0.42	100.56	58.91

* Analysis by J. H. Herndon. † Analysis by L. Magnenat.

1 Ferrous Oxide—No. 1, 4.20; No. 3, 1.12; No. 4, 1.67; No. 7, 3.22; No. 9, 1.12; No. 10, 2.36; No. 11, 1.40; No. 13, trace; No. 14, 2.65; No. 16, 3.31; No. 17, 3.42; No. 20, 3.42.

2 Manganic Oxide—No. 8, 0.47.

3 Manganese Dioxide—No. 9, trace; No. 19, 0.57; No. 21, 5.20; No. 22, 4.78; No. 23, 8.54.

4 Loss by ignition—No. 6, 2; No. 13, 2.10; No. 15, 1.8; No. 16, 0.80.

5 Soda—No. 16, 4.05.

6 Potassa—No. 16, 4.71.

(J) Collected by G. Jermy.

3. THE HYDRATED IRON ORES.

With such high grade bessemer ores as have been reported under the two preceding heads the limonite series would fail to attract any business attention were it not for the unusually rich character of the ores of that division which exist in our region. It is true that the outcrops are not very abundant, and they rarely if ever occur in beds or in segregations of any magnitude. Aside from the insignificant quantity which comes in as contaminations through alterations of the anhydrous ores, these hydrous oxides appear almost exclusively in veins, for the most part in the older rocks. The most important fact connected with their distribution is their occurrence largely in places where there is every reason to believe that they are connected with the buried magnetite ores. They often pursue courses more closely related to the Fernandan trend than to the principal fault lines at surface in the areas where they outcrop, and where they do not follow this law there is usually an irregular development of the veins which roughly corresponds with the distribution of the magnetites in belts beneath them.

Table IV gives analyses of ten samples of hydrated ores from various localities. No attempt has been made to separate them into species. The "loss by ignition" does not, of course, represent the exact proportion of water in all cases, but the general relations of the ores may be understood by reference to that column. *Turgite*, *gœthite*, and *limonite* are the prevailing types, some very fine radiated examples of *turgite* (No. 7) occurring near the divide between Hinton Creek and Deep Creek on the Fredonia and San Saba road. Numbers 6, 13, and 15, of Table III, are partly limonitic. In fact, it is necessary to draw arbitrary lines, owing to mixtures of the principal minerals in the ores. Table III contains a striking example of this in No. 16.

Some of these viens have been worked by persons who have believed them to be rich silver ores. No. 8, Table III, is an example from one of these prospects. As will be seen by the analysis, it is a very good limonitic iron ore, but with rather a high percentage of phosphorus, due no doubt to its proximity to the greensand beds of the Potsdam Series.

The *limonites* may become important sources of revenue in addition to the other iron ores, although they are not abundant enough to sustain any industry by themselves. In some cases, however, as at the Chaney diggings, southeast of Packsaddle Mountain, the quantity is sufficient for profitable working, and the prospect for better ore (manganese or iron) below is very good when the structure is considered. The conclusions here given are based upon many more observations than can be well presented here. There are many localities in the Silurian and Cambrian rocks where veins of this kind overrun, especially in the San Saba River valley.

TABLE IV. LIMONITIC (HYDRATED) ORES.

Localities.

1. Little Llano Creek, Llano County.
2. Cold Creek, Llano County.
3. Near Suttons, Llano County.
4. Iron Mountain, Llano County.
5. Chaney's diggings, Llano County.
6. Garner Crossing, Llano River, Llano County.
7. Hinton Creek, San Saba County.
8. Heard's diggings, near Camp San Saba, McCulloch County.
9. Seven miles west of Mason, Junction City road.
10. Iron Creek, Gillespie County.

	Ferric Oxide.	Silica.	Alumina.	Lime.	Magnesia.	Phosphoric Acid.	Sulphuric Acid.	Loss by Ignition.	Total.	Metallic Iron.
1*1	67.39	14.40	8.21	......	0.54	......	.....	5.20	....	47.17
2*2	64.77	14.95	7.71	0.61	Trace	Trace	0.30	10.10	99.56	45.34
3†2	69.80	21.36	3.10	Trace	Trace	......	Trace	4.40	100.08	48.86
4†	78.83	5.61	3 17	Trace	......	Trace	0.06	12.50	100.81	55.18
5†1	57.65	21.65	3.09	3.20	2.34	......	......	4.45	100.39	40.36
6*	57.54	30.30	1.66	0.48	......	0.51	0.82	9.36	100.61	40.28
7*	86.63	5.20	0.17	1.48	Trace	0.09	0.18	6.60	100.35	60.64
8*	82.60	2.58	1.60	1.15	Trace	0.92	0 20	11.80	100.85	57.82
9*2	46.21	41 58	3.61	.45	Trace	Trace	0.35	5.15	100.03	32.35
10*	79.56	10.80	3.04	4.45	0.04	.26	.39	....	99.01	55.69

* Analysis by J. H. Herndon. † Analysis by L. Magnenat.

1 Magnanese Dioxide—No. 1, Trace; No. 5, 11.12.

2 Ferrous Oxide—No. 2, 1.12; No. 3, 1.40; No. 9, 2.78.

THE FUTURE OF THE IRON AND STEEL INDUSTRY IN CENTRAL TEXAS.

Speaking from the standpoint of a mining engineer, there can be no doubt of the possibilities of a large and valuable output of marketable ore from this region. The writer has already summed up his views upon this point in an article in the Engineering and Mining Journal, New York, published April 5, 1890, in the following words:

It is as the seat of a commanding iron industry that Central Texas must look forward to her glory, in the main. With all the wonderful array of natural resource and artificial forcing which has brought to light the great possibilities of the South in other districts, I do not hesitate to report from actual knowledge that Texas may confidently expect to take very high rank among them all whenever her dormant iron fields become fully known. In amount and quality, and in facility of mining, reducing, manufacturing, and distributing of products, no other State can equal this when the ordinary forces of civilization have been properly applied to utilize what nature has provided. Very extensive deposits of *beauxite*, *limnite*, *limonite*, and other hydrated ores, in many instances not seriously contaminated with silica, occur all through the area of Central Texas; *hematites* and *magnetites*, though more restricted, exist in great quantities over wide belts, and many of these show by analysis that they are

rich in metallic iron and free from undesirable contamination. The distribution of the hydrated ores is practically unrestricted. Workable deposits exist in connection with the widest variety of rocks, from the oldest to the most recent, but the accumulations are chiefly vein deposits and segregations, instead of bog formations. *Hematites* occur in various forms, both as beds and as inclosures in quartz and other matrices. The *magnetites* form a well-marked belt extending across the whole area along certain lines of greatest disturbance.

Without attempting a minute classification, and excluding some notable exceptions, it may be stated in a general way that the magnetic ores follow mainly the trend of the oldest gneisses and schists; that the *hematites*, excepting those of secondary origin, are largelv characteristic of the Lower Potsdam and earlier horizons, and that the hydrated ores are in largest measure direct or indirect alterations of the anhydrous deposits previously defined. As to geographic distribution, although strict accuracy must be disclaimed at present, it is roughly correct to designate the northwest trend and the region in Llano County (with extensions in Blanco and San Saba counties) as pre-eminently the *magnetite* belt. The *hematite* belt par excellence covers a wide area, bearing more nearly north and south, extending through a very large share of Llano and Mason counties, continuing into Gillespie County. The more recent cross trends carry in their strikes as a rule only the secondary deposits of *magnetites* and *hematite* crystals and *limonites*.

Speaking as a metallurgist, it is incumbent upon me to put forth cautionary words against an error which has often blighted the prospects of rich iron regions. While Llano County, and portions of the adjoining counties of Mason and Gillespie, and perhaps limited portions of San Saba and McCulloch counties, are certainly destined to become extensive *producers of iron ores*, the erection of smelting plants is not now justified by the situation. Fuel is not abundant in the area, excepting in a portion of McCulloch County, and it has been the rule in metallurgic practice to ship ore to the fuel and not the fuel to the ore. The reasons for this are obvious. I am not now saying that iron smelting cannot and will not be eventually a success in the district where the ores are produced, but anyone who is competent to form a practical judgment in such matters must quickly discern the fact that the Central Mineral Region occupies a position, commercially as well as geologically, equivalent to that of the Lake Superior region, without the timber supplies of that area. That has been emphatically a mining district, not a smelting centre. With all the bright prospects of our region, it is to be hoped that capital will not be wasted in the attempt to "build bricks without straw." Railroads for transportation are much needed, and the building of these, with the opening of new coal fields, or the development of those already known, will be the first wise step in the creating of a profitable industry here.

V. RARE MINERALS AND PRECIOUS STONES.

The Archæan rocks and the porphyry veins and the intersections of the folds of different ages afford numerous favorable situations for the formation of uncommon minerals and what are ordinarily known as precious stones,

although there may be but few real gems among them. Many of the new and rare minerals will have a ready sale to collectors, who have heretofore been able to procure them at their own prices. While there is enough competition to keep values down to a moderate basis, and while the discoverers of even the more common varieties are often disposed to demand more than they can possibly get for inferior specimens, it is not necessary to accept ridiculously low figures for material which is in such demand as to command very high prices in the market.

If the owners of property in the Central Mineral Region will take the little trouble necessary to inform themselves at a reasonable cost, they will neither expect $10 each for common garnet crystals, nor will they accept 25 cents per pound for the rare minerals which collectors eagerly seize at twenty times that price. But it is important to remember that perfect crystals of somewhat common substances may frequently be worth much more than inferior specimens of the rare minerals in large quantity.

The following summary includes all the known occurrences of commercially valuable materials which owe their importance to variety or fitness for use as precious stones:

1. GARNET.

The garnets are abundant in the Burnetan rocks in Burnet, Llano, and Gillespie counties; and although fine cabinet specimens, showing both large and attractive crystals, have been taken freely from various excavations, it is very probable that better ones will be discovered as the rocks containing them are more extensively worked. The cabinet of the Geological Survey, in the Capitol at Austin, has some very choice examples of these garnets, of several colors—black, brown, and green. *Almandite*, *andradite*, and *grossularite* are the most common varieties. They occur in great abundance in garnet rock, usually associated with *fibrolite* as a thick adjoining rock layer. An exposure in Clear Creek valley, two miles southwest of the Witherspoon crossing, on the Burnet and Bluffton road, has been scratched to some extent, but not systematically nor continuously. Other outcrops in the Babyhead Mountains, King Mountains, and elsewhere, have yielded similar products, but nothing but surface digging has been attempted. The promise of profitable results is great enough in all these places to justify more thorough mining; but this must be done in anticipation of moderate pecuniary returns, not with any reasonable hope of securing gems.

Idocrase or *Vesuvianite* is not strictly a garnet, but is near enough in general characters to place it in the same category for commercial purposes. This mineral is also abundant in similar situations, and some large crystals can be secured, which will find ready sale to collectors.

BARRINGER HILL—LLANO COUNTY.

2. BERYL.

Some very large fine beryls have been found in Gillespie County, and occasionally in Llano County. They occur in the Archæan in situations similar to those in which the garnet abounds.

3. TOURMALINE.

Black tourmaline is abundant in the Burnetan Granites (north 75 degrees west trend), sometimes in large crystals, but it is rarely solid enough to enable one to remove the mineral from the matrix without fracturing. It is also so closely knit together with the coarse and interlocked feldspar crystals that a blow upon the rock or the wedging of the feldspar causes the brittle tourmaline to fall into small fragments. Often the jointage of the granite or porphyry has cut through the tourmaline crystals as well. For any possible uses of this mineral, where size and form are important, the quantity and ease of working is not prohibitory, but there is no prospect that this field can ever afford specimens of much value for cabinets.

ESPECIALLY RARE MINERALS.

A very careful search has been made by us for rare and valuable minerals, and the results have been very satisfactory. So far as present developments enable a judgment to be formed, the Burnetan outcrops seem to be the sources of the most valuable varieties. There are several localities in which the geologic conditions are identical with what have existed in the only tract actually known as a commercial producer of the rarest minerals to-day. Prospecting for such material has not been general, although there is every reason to believe that many of the exposures will be found prolific if properly worked.

A. THE BARRINGER TRACT.

The discoveries thus far have been almost wholly confined to the limited outcrop at Barringer Hill, in Llano County, upon the west bank of the Colorado River, about four and a half miles south of Bluffton. This locality has already been described in this Report, and a list of occurring minerals has been given in the discussion of the rocks of the Burnetan System.*

An engraving from a photograph is appended, the view being from the river side, looking southwestwardly towards the excavation from which the latest and best specimens of gadolinite have been mined. Lack of time and press of other analytical work has prevented the proper study of these minerals which were to have been described, and they must be left until the next report.

*See page — of this volume and the photographic view.

B. OTHER SIMILAR LOCALITIES.

Broad belts of quartz occur in the same trend as at Barringer Hill, in many parts of the Burnetan exposure west and east of that locality.

East of Nigger Head Peak, a little southwest from High Point, in Burnet County, on a branch of Clear Creek, there is an outcrop of quartz which may be an extension of the Barringer dyke.

The "pressed" feldspar characteristic of the latter belt is not evident, but a granite, with peculiarly fine crystallizations of orthoclase and rare minerals, intersects the white quartz in much the same manner.

There are enormous quartz belts following an equivalent trend in the Babyhead District, especially in the western part on Wolf and Pecan creek headwaters. Some of these may have similar feldspathic associations. The graphic granites and their allies—the complex feldspars—seem from present knowledge to have an important relation to the occurrence of the rare minerals in such situations, but we do not yet clearly understand the real nature of this influence.

In the westward continuation of the strike of the Burnetan rocks from Barringer Hill, wherever good exposures can be found, there is reason, I now think, for expecting similar results from careful prospecting. It is wrong, however, to hope to make a business success out of any but the most systematic mining of such deposits. The work done at the Colorado River has been desultory, irregular, and without system.

Other belts of the Burnetan quartz cross Llano County southward, and parallel outcrops may possibly be opened in Llano and Gillespie counties, in the bay of Archean rocks which runs southeast of Enchanted Rock towards Blowout and Willow City.

The belief in the relations of the feldspar and graphic granites to the gnesses of the rare minerals is strengthened by the fact that prospecting thus far has been unsuccessful in the quartz belts which are unaccompanied by the irruptives aforementioned.

VI. BUILDING MATERIALS.

The *Central Mineral Region* is rich in rocks suitable for construction. Some of them have been already proved in practical use in store houses and dwellings, and others have much more than a local reputation. Many which have not been so employed will, no doubt, become commercially valuable when railroad transportation shall have made them accessible to markets. As yet, however, there has been no systematic testing of any of the strata, so that it is not possible to report in detail concerning the strength and durability of these natural products. Such facts as have been gathered are here

presented merely as a preliminary report. For practical purposes the best discussion of the subject may be made topically by substances as below:

1. THE GRANITES.

To treat this division fully it would be necessary to arrange the granitic rocks of our district into not less than seven or eight distinct types, each characteristic of one particular uplift among those which have been described in Part I of this Report. Commercially there will be as many or more varieties whenever the demand has sufficiently stimulated the development of the the resources of this kind in Llano, Burnet, Gillespie, Blanco, and Mason counties, named here in the order of area of exposures, beginning with the largest.

It would be very difficult now to so describe each one of the granites so clearly that any one could determine by simple inspection which type he is handling. Nor can those who will work them usually make geologic distinctions based upon differences in the modes of occurrence; for the chief criterion—the strike of the mass—is in very many cases only determinable from a knowledge of the texture itself. When numerous quarries are shipping the different grades, a commercial classification may be adopted which will not agree closely with the one here proposed, but there is a kind of textural relationship which makes this provisional arrangement at least of temporary value. Adopting then as a basis of affinity the structural characters, using texture, colors, etc., as a means of further division when necessary, we get seven fairly distinct classes, viz.: *A, Gneissic Granites; B, Compressed Granites; C, Block Granites; D, Friable Granites; E, Mixed Granites; F, Dimension Granites; G, Fissile Granites.*

Only in a very general way may this be regarded as a scientific grouping, but in proposing it an attempt has been made to get as near to the order of formation, or age, as can well be done without more intimate knowledge of the outcrops than has yet been acquired.

A. THE GNEISSIC GRANITES.

These are gneisses and quartzose mica schists in the Archæan exposures, which do not offer any prospect of becoming valuable as building material, unless it may be for restricted and commercially unimportant uses. But, in addition to these, extensive masses of compact, streaked granites, usually fine-grained and sometimes easily workable, occur in the oldest rock systems, especially in Llano County. If the best of these can be quarried in places where they have been least disturbed by more recent uplifts, as in parts of the Babyhead region, and perhaps also in the Burnet County granite tract between Spring Creek and Clear Creek, it is very probable that excellent

speckled and mottled varieties may be obtained. These will frequently polish with good effect, and some outcrops show by their style of weathering that certain oxidation tints of value for ornamentation may be utilized. In working this class, however, great care will be necessary to select only those qualities in which the mica is well distributed and in comparatively fine scales. Otherwise serious blemishes may result from irregularity of "weathering."

For paving blocks, foundation stones, and special uses, much of this material may be utilized eventually at little cost.

B. THE COMPRESSED GRANITES.

There are many of the Archæan granites which appear as if tightly wedged in between the adjoining strata, although the result is perhaps more often due to the expansion produced by the crystallization of the magma. For this last reason the material is frequently an aggregation of large interlocking crystals, without coherence enough to render the rock useful for any purpose where stress is anticipated. Occasionally some very fine crystals of *orthoclase* and *microcline* of immense size, or tough masses of graphic granite admitting of a high polish, occur in similar situations. *Adularia* in crystals of good size is also abundant, and this may find a use economically, if not for building directly.

C. THE BLOCK GRANITES.

This name is proposed for a class of granites which occur in various parts of the Central Mineral Region, and which may represent more than one uplift. They are not yet fully understood, and there is here no intention of putting them together except for the convenience of treatment. They shade off into dimension granites upon the one hand and into fissile granites upon the other, in a general sense, and yet they are distinctive, more by reason of their texture than their structure. At the same time it is possible that some of the friable granites, or "rotten granites," may be only the block granites undergoing a process of decay. But a commercial classification must necessarily deal with present conditions, and upon that principle this class name is justifiable. I would include under it all those granites which are solid enough to withstand sharp blows from a single-hand hammer without shattering, except along the line of impact, so that they may be readily broken into blocks. But, in addition, they must have definite joint or lamination planes, usually induced by the mode of arrangement of the large crystals of feldspar. Any of the other types, howsoever well they may be broken into shape by careful trimming, do not at once assume the block form characteristic of this class. Thus restricted, there is considerable variation in the solidity of the blocks, even when they are not undergoing rapid disintegration. This difference arises from the irregularity of coherence among the

feldspar crystals. Some of the block granities are less ferruginous and paler in color than the classes previously described, but when there is an abundance of siliceous cement this loss of iron does not appear to weaken the combination.

As limited above, the thickness of these rocks varies from a single layer of original crystals to an aggregate of one foot in all. They occur all over the district, but are perhaps most common in the mid-belts of Llano County. In the absence of actual tests it is not possible to state their applicability in the building art, but it is not probable that they will usually withstand great pressure, unless understandingly applied in masonry structures specially planned to distribute the stresses unequally in definite lines. Care should be taken to study the lamination planes and the position in the quarry, and to lay them in equivalent positions in walls. Some of them may be adapted for use in pavements and in buried foundations. Although refractory to a certain extent, they would probably succumb to excessive temperatures, and they are illy fitted to resist sudden changes of temperature. As a rule they are not ornamental.

D. THE FRIABLE GRANITES.

Probably many of the other granites will decay and crumble under the influences of stratigraphic agents, and much attention ought to be paid to the surface exposures and the selection of the best qualities in every case. Some technical knowledge and practical experience is necessary to enable one to choose the material understandingly. In places, as much as twenty-five to thirty feet of rotten granite is now covering hard granites of the same class from simple decay *in situ*. The friable granites here included, however, belong to another category. They are perhaps as well described by the title "sandy granites," as they are fine-grained, granular, not very coherent, and commonly quartzose. These occur abundantly in our region, especially in the border areas, representing chiefly a Pre-Cambrian uplift, and they sometimes grade off into sandstones. Another older set, which may be included with these, comprises the sandy gneisses of Lockhart Mountain and other districts. None of these have any value in construction, although it may be possible to utilize a portion in some way connected therewith. Their best application will be for road making.

E. THE MIXED GRANITES.

The Post-Silurian uplift, as previously announced, brought up a magma which is now exposed in Honey Creek, Llano County, and in Honey Creek, Mason County. This has been referred to as the bearer of schist inclusions.

So Mr. Walcott interpreted his observations, and the writer has adopted this view in another part of this Report.

But, it will be noted that the occurrence of welded inclusions was described. Many of these appear like syenite blotches, and this view is strengthened by the occurrence of large masses of very similar syenitic granite, apparently of the same trend and age, in Silver Mine Hollow, a branch of Beaver Creek, Burnet County.

Whatever may be the final conclusion regarding these granites, their texture is well known now. Excepting such exposures as the one just mentioned in Burnet County, there will probably be but little demand for such irregularly patched material, although it is solid and some choice combinations might be secured at cost of much time, labor, and capital. The dark grey granite from Silver Mine Hollow may become especially valuable from its variety in this region, and probably other exposures may be found southward in favorable situations.

F. THE DIMENSION GRANITES.

The best of all our sources of granites for general construction, including foundations, superstructures, and the heavier ornamentation, as well as mural and monumental works, is that known as the "Burnet Granite," from the original source of supply in Burnet County. To one wishing to know of its adaptability, durability, and general appearance, the example of its use in the stately edifice—the Capitol—at Austin need only to be given. This type, of which there is an enormous quantity in the Central Region, is undoubtedly to be an incalculable source of future revenue. Although enough has already been quarried to exhaust properties of important proportions, there are thousands of times as much awaiting easy extraction. Many believe that the "Capitol Granite," as the rock is sometimes called, is confined to one large outcrop near Marble Falls, the one from which all the material for the State Capitol was taken. This is a grave error, for the outcrop extends over an area of nearly one hundred square miles, and there are others further west which cover in all nearly as much more territory. Enchanted Rock and its environs in Llano and Gillespie counties, expose nearly as much, owing to the great height of the peaks, although the horizontal outcrop is less. There is also an area in Mason County, near Katemcy, where about 1000 acres are exposed in a considerable elevation.

This is probably as well exposed for working as any similar mass in the world, and for many purposes the material is not inferior to some of the best foreign granites. It has a pleasing appearance, whether used "in the rough," dressed, or polished, and it can be quarried in almost any desired form of practically unlimited dimensions.

The color is red or dark reddish-grey, and there is a considerable range of choice. In combination with the other granites, by judicious alternations or different modes of treatment, but little is needed to obtain the widest variety of ornamentation of which the darker granites are capable. There are other exposures of "dimension granites" in situations which make it possible that they belong to a different uplift from that of the Capitol Granites. In the Wolf Mountain, north of Llano in Rabb's pasture, a rock of this character has been locally applied with success in building small structures. This has features which place it in a transitionary position between the block granites and the Capitol granites. It has an attractive appearance, being more nearly purple or blue in color than its red-grey compeers.

Dimension granite also occurs in abundance in some variety in the belt which runs through the Archæan rocks in Burnet County, extending from Capitol Rock, between Spring Creek and Clear Creek. It is probable that the rough country in this tract is made up of outbursts of different ages. Some quarries have been opened in the area and good material has been obtained, but the demand has not yet caused any extensive development of these resources.

It is a mistake to suppose that the dimension granite is restricted to the Post-Carboniferous uplift, to which the Capitol granite belongs, for there are important outcrops in other masses in various parts of the region.

G. THE FISSILE GRANITES.

The Cretaceous uplift brought up a class of granite of somewhat irregular character but commonly fissile, bearing north 30 degrees east in the outcrops. Some of these are possibly of some value for the more severe uses, but they are not likely to attract especial attention, owing to their general inferiority to the neighboring Capitol granites. But there is variety enough in intimate texture to make some of these possibly useful for trimmings and for particular purposes. In the neighborhood of Enchanted Rock upon the east there is a line of elevations, including Sentinel Peak, which appear to owe their resisting power to infiltrations of beautiful porcelain-white quartz, which has filled the interstices and produced a rock of some possible ornamental value. There are other fissile granites and gneisses in the different uplifts, some of which may be of economic importance, but none of them have yet been tested.

2. THE MARBLES.

There are at least three possible sources of marble in the Central Mineral Region, although it is not now practicable to report just how valuable these may be. The surface outcrops are not always the most reliable indications

of character of this kind of product, but we may get important hints from such observations as have heretofore been possible.

A. THE FERNANDAN BLUE MARBLES.

I do not think it probable that the oldest blue marbles (Fernandan) occurring in the northwest trend, in connection with the magnetic iron belts, will be found satisfactory for anything but a limited range of application. They are usually thin and much broken by joints, their dark streaky color is objectionable for most uses, and they are often pyritous. This last feature renders them liable to stain badly upon exposure, owing to decomposition of the pyrite. Careful selection, after much prospecting at some depth beneath the surface, may prove that these opinions are unfounded, but it will be wise for those who desire to use the material to get expert advice as to the probable effects of long exposure.

B. THE TEXAN WHITE MARBLES.

Much more promising are the white marbles of the Texan System, coursing north and south in their earliest trend. These are often snowy white, even grained, fully compact, and there appear to be strata among them of medium thickness. In prospecting for these care should be taken to select localities in which the meridianal trend is prominent, as in the district south of Packsaddle Mountain, and perhaps more surely in the Comanche Creek Region, in Mason County. The exposures are more abundant in the former area, but probably less affected by the later uplifts in the latter tract. It does not now seem likely that any of these marbles can be made to compete with the more massive and more easily worked products of the Eastern States, but some local application of them may be possibly made profitable eventually.

C. THE SILURIAN MARBLES.

There is more hope for some of the compact dolomytes of the Silurian System, especially those in the Hoover Division of the Leon Series, and perhaps selected beds in the San Saba Series.

Burnet, Blanco, Gillespie, Mason, San Saba, and McCulloch counties have many good exposures of the Hoover Beds. There is, however, much variation in quality in the different outcrops, and it is as yet uncertain where the best commercial products may be raised. In testing outcrops it is very important to ascertain how seriously the rocks have been affected by the various upheavals, because breaks which do not show in faults or master joints may be dormant in the mass, ready to be developed upon exposure to the elements. This source of annoyance is more fully explained beyond, under the head of Lithographic Stone.

These are the so-called "Burnet Marbles." Really tney are not true marbles. Very beautiful pink, white, buff, blue, and grey varieties may be obtained from these beds, and in some cases, especially in McCulloch and San Saba counties, the variegated marbles are somewhat abundant. In some places the strata are thin, but in others slabs and blocks of considerable size may be taken out. The rock is tough, often having a semi-conchoidal fracture, and it dresses well, sometimes admitting of a high polish. Upon the whole, there seems to be a reasonable basis for a profitable industry in the utilization of this class of material.

Some other beds, especially the saccharoidal and birdseye types, may hereafter become serviceable as pseudo-marbles, but no attempt has been made thus far to use them. Their outcrops are northward upon Cold Creek, for the most part in San Saba and Burnet counties.

3. THE COMMON DOLOMYTES.

There are very few simple limestones in the Central Region among the Pre-Carboniferous rocks, to which our present review is limited. Nearly all the calcareous rocks are dolomytic, excepting some tufas and calcareous sandstones of little value. The Cambrian dolomytes may occasionally serve useful purposes as material for fences, buried foundations, and bridge piers, for many of them are durable enough, and they can often be obtained in convenient sizes; but their sombre hues and uneven weathering unfit them for employment in the better class of buildings. Exceptions may be found, but the statement is very generally applicable. The Silurian Beds afford a wider variety, but being dolomytic, and thus weathering black or brown, much care is necessary in selecting them. A good rule is to reject those which are unsightly in old natural exposures, however attractive they may be upon fresh fractured surfaces. Some of the yellow dolomytes of the basal Silurian may, perhaps, be effectively used as trimmings, or even as regular building material, and it may be possible to select other beds from among those which are most even and attractive in natural exposures. There is nothing except the marbles already described which will be liable to command an outside market, although local requirements may sometimes be met to advantage by such supplies of the kind as the district affords.

The Devonian dolomytes are unsuited for construction.

4. THE QUARTZITES AND SANDSTONES.

There are some altered sandstones or quartzites which may become useful where they can be quarried in sufficient quantities or in blocks of suitable size. As a rule these are of ancient origin. They do not occur so regularly or of such uniform character that a general statement as to their distribution

can be made applicable. It will be necessary to make special search for them. The area of most promise is between the Riley Mountains and the west line of Llano County, or a little further west in Mason County. The red color is against some which might otherwise be serviceable, and others are too fragile, owing to the ready decomposition of a feldspathic ingredient. The sandstones proper are all Cambrian. Some of these upon the outer edges of the district may be adapted for building uses, but they are not all of such quality as to make them desirable. By selection it may be possible to get some very uniform and pleasing varieties of red sandstone, but the difficulty will be to find places where metamorphism has sufficiently hardened the rock without at the same time cracking it too much for service. A notable exception is the yellow indurated sandstone of the Lower Cambrian. This, as exposed upon Packsaddle Mountain, House Mountain, Smoothing Iron Mountain, and elsewhere, is a massive tough rock, semi-quartzitic, with siliceous cement, occurring in layers ten feet and more in thickness. Undoubtedly useful applications of such material will not be lacking, and it is often favorably exposed for working.

The white sandstones, like the red, are usually too fragile for purposes of construction except for use in mortar and plaster.

5. SLATES, PORPHYRIES, ETC.

There is some prospect that certain of the fissile strata of the Archaean and Algonkian belts may become valuable as roofing slates, although the surface exposures are often so much altered that determinations of quality are not always conclusive. The area in which the Burnetan, Fernandan, and Texan rocks are now uncovered will be the proper places in which to seek these outcrops, but the later uplifts have occasionally brought them to view in a more or less contorted condition. To test material of this class, it should be soaked for a day or two in water, subjected to a drying heat, and then suddenly plunged into cold water. If the absorption be slight and the materials do not materially change by flaking, crumbling, or softening, the rock is liable to be serviceable, although one familiar with such tests should be called upon to decide finally. The porphyries do not impress one with being of much economic importance except in a few instances. There is a tough, dark-green to black hornblendic rock crossing the upper valley of Cold Creek in the northern portion of Llano County, which may perhaps be utilized in some way. Probably it might make good paving material, and possibly it could be successfully used for ornamental use in building.

There are also some red porphyries which a vigorous development of the interior may eventually make valuable in the arts; but with the foregoing

exceptions, nearly all the rocks of this character are either too coarse and fragile or too soft and friable to be of any material service.

Soapstones of excellent quality for fire proof linings and other materials which may have occasional applications in construction, will be discussed under the head of Refractory Materials.

6. CLAYS FOR BRICKS AND CEMENTS.

As might be inferred from an inspection of the geologic structure, sands are much more abundant than the clays in our region, especially in the granitic core of the region. Occasionally some excellent clays, both ferruginous and non-ferruginous, are to be had along the borders of this tract in situations not far removed from the Cretaceous and Paleozoic strata. These will probably attract notice from their great variety more than from their abundance in any one locality. The conditions for the accumulations of numerous kinds of clays have existed over much of the tract, but it will require special observations to give a full statement of them. We are doing all we can to accumulate facts upon these topics, but the variety of work necessary to classify them is very great.

7. DECORATIVE STONE.

The serpentine and other rocks which might have an application as decorative stones are not probably present in our district in such desirable forms as to make them useful upon a large scale. But when the industrial development of the region has assumed important proportions, many of the more durable and attractive rocks not now noticed may become sources of revenue on account of special adaptations. Probably some of the brilliant red sandstones and the chocolate limestones, or even the tougher greensand strata may thus be utilized, although they are not commonly strong enough to resist heavy pressure in ordinary construction.

8. MATERIAL FOR LIME, ETC.

The limestones may be used in some cases for the manufacture of lime, the best quality being produced from the chalky Cretaceous strata which lie nearly horizontally along the borders of the district and in the great inlying promontory known as the Mason Mountains. Many of the Silurian limestones are too siliceous for making good lime, but some of them are more suitable.

The Potsdam limestone division of the Cambrian System has strata which can be utilized for this purpose.

Hydraulic limestones are not known to exist in the Pre-Carboniferous rocks of the Central Region, although some of the Silurian shaly beds, and even the shaly portions of the Potsdam limestone, may be worth testing.

Sands for concrete of various tints may be readily obtained at surface in many places. For the most part these are very pure, and no doubt other uses will be found for them whenever the demand arises. Red sands from the waste of the Cambrian sandstones are especially prevalent. Hematite sandstones have already been referred to in the discussion of the iron ores. The decay of these has produced in many cases extrusive tracts of brilliant red sands, some of which are noticed beyond under the head of "Materials for Paints."

VII. REFRACTORY MATERIALS.

Many of the rocks referred to under the head of building stones may be applied in situations where great heat is required, and there are besides not a few other kinds which will resist high temperatures. Probably the acidic schists may often be so employed to advantage, and in cases demanding such materials the tough basic slates and schists are all that can be desired.

The Cambrian and Silurian rocks are not suitable for such uses as a rule, but the Pre-Cambrian exposures are readily accessible and widely distributed. It is only necessary in this place to notice a few specially important substances, which may hereafter have more than a local value.

I. SOAPSTONE.

I have not yet seen any steatitic rocks which give promise of becoming important except as fire-proof substances, although some of the talcs and soapstones are pure and free from grit. They are almost invariably foliated to such an extent as to prevent their application in other ways, unless in the powdered condition. So far as now known the talcose rocks are confined to the Burnetan System, although their absence from the Fernandan outcrops is not certainly proved. They may occur in other trends than the earliest (north 75 degrees west), but as yet none are known to belong to any of the later systems. One of the best exposures is about two miles south of west from the Smoothing Iron Mountain, in the valley of San Fernando Creek, in Llano County.

This has a semblance of foliation, but it may be sawed or cut into blocks and slabs with a smooth exterior. As a lining for furnaces and for other purposes not demanding a decidedly firm texture, the material is excellent. Some care may be necessary in the selection to prevent flaking or exfoliation, but the rock is superior to much that has been marketed and used with apparent satisfaction. Most of it is not pure white. Grey is as nearly a description of its tint as can be given in one word. Sometimes there is a speckled or marbled appearance upon freshly cut surfaces. The quantity is great enough to supply a large industry, and careful search along the strike

of the outcrops, with some stripping in places, will reveal much more than is generally believed to exist. The most favorable district for explorations is in the district between House and Smoothing Iron Mountains and the King Mountains, and west of that area in Llano and Mason counties, but the chances are very good further eastward and southward in Llano, Gillespie, and Blanco counties. Northward in Llano and Burnet counties there may also be other occurrences in accessible situations. We are speaking now of talc and steatite, not of the various clays and other deposits which are often popularly but incorrectly termed "soapstone."

2. ASBESTOS AND ALLIED SILICATES.

It is very commonly believed by residents of this region that asbestos occurs in masses of workable extent. I have not yet observed an instance of this, nor do I know of any occurrence of the mineral, unless it be in Blanco or Gillespie counties, beyond the limits of my observations to date. In private collections there are numerous specimens of so-called "asbestos," the principal part of which are very fine examples of fibrous aragonite, a mineral of entirely different composition. Asbestos is an anhydrous magnesia-lime silicate, a variety of Amphibole, allied to hornblende and tremolite, while aragonite is a carbonate of lime, differing from calcite only in being harder and heavier.

Asbestos is tough and unaffected by heat or acids; aragonite whitens and falls to pieces when strongly burned, and is rapidly dissolved by acid, with brisk effervescence.

Another mineral, occasionally found in small quantity in the rock of this region, has sometimes been reported as asbestos. This is tremolite, which is near asbestos in composition, being a white variety of amphibole. It is not fibrous like asbestos, but occurs in thin-bladed crystals. Other specimens, labelled asbestos in some collections, is fibrolite, a tough, semi-fibrous white rock usually accompanying the garnet of the Burnetan exposures.

VIII. MATERIALS FOR GLASS AND POTTERY.

In the white sandstones of Castle Rock and Rock Fort, and the great areas covered by the waste of the same beds in Llano County, especially along the sources of Willow Creek and Phillips Creek, there is every probability that excellent material exists for the manufacture of glass. No tests have yet been made, but the sand is remarkably pure and in enormous quantity.

Pottery clays are not abundant, probably, although there are places in many of the creeks where very fine clays have been deposited, and in parts of the Burnetan exposures there are good occurrences of *albite*. A sample of this mineral from Clear Creek, Burnet County, contains only 1.09 per cent

iron, as per analysis by Mr. J. H. Herndon, of this Survey. Feldspar of this grade can readily be duplicated in the region in marketable amounts. Orthoclase, very pure but ferruginous, can be mined *ad libitum* from dikes and patches in the Archæan rocks. Kaolinite is abundant as an alteration product, largely of the variety *carnat*, chiefly pink; but this does not occur in deposits of appreciable size, so far as known.

IX. MATERIALS FOR PAINTS.

It may be that some of the deposits of the softer red earths, which are little more than degraded hematites, will come into service as pigments, and even the more siliceous red sands may afford materials of value for similar purposes.

The graphitic schists of the Fernandan System and the graphitic shales of the Texan System do not appear to afford enough carbon for use in this manner, but if any important deposits exist, like one on Cat Creek examined by the writer, there is a chance of obtaining some revenue from them. The Cat Creek triturated graphite is a kind of bog deposit locally found in old pools in the bed of the stream, where this material has been silted-in with layers of clay and sand. It was shown to me by a gentleman who thought he had discovered a bog manganese ore. The black earth is, however, very similar to the "black mud" of the Bear Creek district in Arkansas,* but it has been produced in a different manner. Not far above the Llano County deposit the graphitic schists cross the creek, and this accumulation has undoubtedly come from that source. With such enormous quantities of very pure material in Arkansas, the product of numerous hot springs which have worked over the earth and assorted it thoroughly, there is little prospect of putting our limited and inferior supply into marketable form so as to realize any profit.

X. MISCELLANEOUS ECONOMIC PRODUCTS.

Under this head are included some of the natural sources of revenue which this district affords, as well as other materials which require some notice here, by reason of the efforts heretofore made to utilize them economically. These can better be treated under one general head than to classify them independently.

1. LITHOGRAPHIC STONE.

Many residents of Burnet and San Saba counties have based great hopes upon the supposed adaptability of some of the Hoover (Silurian) strata for

*See Report of Geological Survey of Arkansas, vol. I, p. 104. Theo. B. Comstock.

use as lithographic plates. There are not a few to-day who believe in this rock as a future source of prcfit, thus employed. This material is the compact grey or dove-colored Burnet marble, previously described under the head of Building Stones and elsewhere in this Report. The abundance of the material, its good exposures for working, the proper thickness of many of the layers, and the good general appearance of the stone, are all favorable; the small specimen pieces exhibited by interested persons often show well in grain, in their reception of inks, and even in the quality of the lithographic prints obtained from them. Were this rock of late geologic age, so as to be free from structural and textural alterations due to upheavals and infiltrations, it might be very well adapted to use by the lithographer. But, unfortunately, practical tests do not bear out the promise of superficial examinations. Upon surfacing the stone, minute seams, flaws, or cracks are always developed, so as to make it unfit for this purpose. Since the deposition of the material in the Silurian Sea there has been too much disturbance and too much alteration to leave a uniform texture except in very small pieces, and the uncertainty of the positions of the defective spots before grinding is an effectual bar to the employment of such a product. Often in working out one defect several others are made apparent. After much study of the outcrops of the Hoover Beds, I am reluctantly compelled to report that there is little chance of obtaining any slabs of lithographic stone of a large enough size for the building up of a profitable industry.

There are no other rocks in Central Texas which are of any value for lithographic plates.

2. SALT.

I have not yet made a detailed examination of the salt spring in Llano County a few miles northwest of Bluffton. Under the stimulus of an unusual demand, or for other reasons, the brine at this locality was formerly evaporated with some success; but nothing has been done in this way of late. Preparations for the work were made upon a somewhat extensive scale, and the cause for abandoning the enterprise is not evident; although it is also difficult to understand, without much study, what could have given rise to a really valuable brine or salt deposit in such a situation. The locality is in the midst of the Archæan outcrops, but Silurian beds are not far distant, and it may be that some of them are the sources of supply. It is difficult to believe in any mere local deposit, however, if such is the origin. Especial attention will be given in 1890 to the district in which the Silurian Beds outcrop in this region.

3. BAT GUANO.

The caves in the Silurian strata about the sources of Beaver Creek, in Burnet County, are many of them enormously rich in bat guano. Some general notes have been taken upon this locality, but a more detailed description is reserved for the Report of 1890. Mr. Charles Huppertz, who was sent to this cave in February, 1890, makes the following brief statement:

The bat cave in the northwest corner of Burnet County is worked by a Georgia company, and I learn from the men at work there that about 157 tons of the material had been shipped up to December 20, 1889. The shipments are made by wagon to Lampasas, Texas, and from there by rail to Georgia and other parts of the United States. The cave is situated about eight miles from Bluffton, going north up Beaver Creek. Near Lacy Branch, a tributary of Beaver Creek, about two miles north of Silver Mine Creek, there is a fault on the west side of Beaver Creek, in a branch which is called "Bat Cave Hollow." Proceeding from this point in a northwest direction for about two miles we reach the bat cave, on top of a higher chert bed. The way from Beaver Creek to the cave is constantly ascending, first over Silurian limestone for about one mile, when the chert formation appears. On the top of a chert hill there is an opening of about ten feet in diameter, extending perpendicularly downward for 30 feet, where at the north side of this opening there is an entrance to the cave. The cave has not been measured, but I estimate its length from north to south to be about 600 yards, with as much, if not more, space in the opposite direction. The top of the cave, as well as its sides, is solid chert, such as occurs in all the chert beds in San Saba and all the neighboring counties. The guano bed in the heart of the cave has been burned, leaving the ashes at places 26 feet deep, and not less than 18 feet at others. The ash is not brought up, and the supply of guano is taken from the surrounding portions and sides of the cave. As I understand, there are some leaders to the cave that have not yet been explored, there being plenty of material near the heart of the cave for all present requirements. Five men were employed in digging and bringing out the guano, by means of a rail track, to the surface, where it is deposited upon a large platform erected for that purpose. At the slope of the cave hill is a large everlasting spring, running into Beaver Creek, near the falls of the creek, depositing on its way large quantities of calcareous tufa, covering the limestone at points to a depth of ten feet. There are other springs near by coming up on top of the limestone, which fact, I think, is evidence of extensive faults all through this section, which are perhaps caused by the sudden upthrust of a granite mass through Beaver Creek, just above the mass of Lacy Branch. Strike south 20 degrees west, dip above the granite northeast, and below southeast.

The writer of this report has not yet visited the locality, but a large sample of the guano sent in by Mr. Huppertz is of very good quality. Analyses and other tests are under way, but are not yet far enough advanced to enable a report in detail to be made before these pages go to press.

PART III.

LIST OF MINERALS COLLECTED BY THE SURVEY FROM THE CENTRAL MINERAL REGION.

The following list of 111 minerals includes only those which occur as crystals or in special or rare situations. It is not complete, but will serve as a preliminary list of localties. The new minerals have not as yet been analyzed, so that it is impossible to describe them at present, but several which seem to be of some interest have been detected in districts like Barringer Hill. A very large amount of material is in the possession of the Survey, and many notes have been taken which have not yet been classified.

Actinolite. (Amphibole var.) Magnesium-calcium-iron silicate.

Beautiful pure bladed crystals, in quartz, at King Mountains, Llano County. Riley Mountains, Llano County. From schist area, near Click, Glen, and Sandy gaps.

Adularia. (Orthoclase var.)

Barringer Hill, Llano County. King Mountains, Llano County. Cold Creek, about line of Llano County. Edge of spur south of Kothman's Water Gap. Martin Creek, Mason County.

Agate. (Quartz.) Silica.

Spring Creek, Burnet County. Banded chert and flint in Silurian rocks; also in San Saba and McCulloch counties.

Albite. Aluminum-iron-manganese-calcium-sodium-potassium silicate.

Spring Creek, Burnet County. Clear Creek, Burnet County. Barringer Hill, Llano County. Little Llano Creek, near Lone Grove, Llano County. King Mountains, Llano County (not abundant, but in good crystals).

Allanite. Cerium-aluminum-iron-calcium silicate.

Barringer Hill, Llano County. Mexican diggings, near Babyhead Creek, Llano County.

Almandite. Iron-alumina garnet.

Mexican diggings, Babyhead Creek, Llano County. Clear Creek, Burnet County. Near Shannon's quarries, in Burnet County, in great variety of colors.

Amazon Stone. (Orthoclase var.)

Several localities in Llano County. Not common.

Amphibole. Magnesium-calcium-iron-aluminum silicate.

Headwaters of Cold Creek, Llano County. Riley Mountains, Llano County. From schist area, near Click, Glen, and Sandy gaps.

Amphibolyte. Amphibole rock. *See* Actinolite, Asbestus, Hornblende, Tremolite.

Near Little Llano Creek, on Houston and Texas Central Railroad land, Llano County, occurs with malachite and in places with magnetite. Also from Babyhead Creek region. Headwaters of Cold Creek, Llano County. King Mountains, Llano County (alterations from actinolite). Comanche Creek, three miles west of north from Mason, Mason County. One mile a little north of west from Koochville, on branch of Comanche Creek, Mason County (carries copper stains). Six miles from Llano, on road through Click Gap, Llano County. Honey Creek, Llano County.

Andesite. Aluminum-calcium-sodium-potassium-magnesium silicate.

Right bank Little Llano Creek, below Lone Grove, Llano County.

Andradite. Calcium-iron-aluminum-magnesium silicate.

Babyhead Mountains and Babyhead Creek, Llano County.

Ankerite. Calcium-magnesium-ferrous carbonate.

Spring Creek, Burnet County (alteration from calcite). High Point, Burnet County. Near Sutton's, northwest of Long Mountain, Llano County.

Apatite. Calcium phosphate.

High Point, Burnet County. Packsaddle Mountain, Llano County (in some of the greensands of Cambrian age). Small green crystals in quartz, opposite Long Mountain, in Burnet County.

Aragonite. Calcium carbonate.

South of Llano, Llano County. Southeast of Enchanted Rock, Gillespie County. Mason and San Saba road, one-fourth mile northeast of Bartons. Hinton Creek, San Saba County. Caylor's diggings, Mason County.

Asbestus. A fibrous amphibole or pyroxene.

Very rare, but occasional in Gillespie County.

Azurite. Hydrous copper carbonate.

Mexican diggings, Babyhead Creek, Llano County. Near Yoakum Creek, Llano County. Miller's mine, Llano County (occurs with epidote and pyroxene). Captain McGehee's property, head of Little Llano Creek.

Beryl. Aluminum-glucinum-beryllium silicate.

Gillespie County, occasionally in large crystals.

Beauxite. Hydrous aluminum-ferric silicate.

Silver Mine Hollow, Beaver Creek, Burnet County. Near Suttons', northwest of Long Mountain, Llano County (occurs in quartz). Little Llano Creek, seven miles above Lone Grove. Near head of Cold Creek, Llano County. Near Smoothing Iron Mountain, Llano County. King Mountains, Llano County. Near Field Creek, Llano County. East of Voca, McCulloch County. West of Voca, McCulloch County. Voca and Camp San Saba road at crossing of San Saba River, McCulloch County. North Mason Mountain, Mason County. Little Bluff Creek, Mason County. Usually mixed with other hydrous iron ores.

Biotite. Hydrous aluminum-ferric-magnesium-potassium silicate.

Shannon's quarries, Burnet County. Near Spring Creek, Burnet County. Clear Creek, Burnet County. Barringer Hill, Llano County. Near Lone Grove, Little Llano Creek, Llano County. North of Lone Grove, on Fisher and Miller survey, Llano County. Miller's mine, Llano County. Johnson's Creek, Llano County. King Mountains, Llano County. South of Panther Creek, Field Creek, Llano County. Southeast of Camp San Saba, McCulloch County. North of Mason Mountain, Mason County. Honey Creek, near Menardville road, Mason County. Rabb's pasture, Llano County. North Sharp's Mountain, Llano County (in granite). Near Garner? Crossing, northwest of Gainesville, on Llano River, Llano County (in graphic granite).

Bornite. Copper-iron sulphide.

Capt. McGehee's property, head of Little Llano Creek, Llano County.

Braunite. Manganous-barium silicate.

Riley Mountains, Llano County. Chaney's diggings, south of Packsaddle Mountain, Llano County.

Bronzite. Magnesium-ferrous-aluminum silicate.

Head of Clear Creek, Burnet County. Near Gainesville, on Llano River, Llano County.

Calcite. Calcium carbonate.

Abundant in veins and special deposits in common forms. Rhomb spar occurs in faults and fissures, especially of the east-west trend, in the San Saba drainage, among Silurian rocks; also in Packsaddle Mountain, Llano County, in a similar situation. Localities: East prong of Packsaddle Mountain, Llano County. San Saba River, below Five Mile Creek, Mason County. Hinton Creek, San Saba County. *See* also Calc-Sinter, Travertine.

Calc-Sinter. Calcium carbonate.

Common in limestone exposures, as encrusting layers about old springs, often forming psuedo-structural masses and making up some extensive beds of agglomerate and travertine.

Carnat. (Ferruginous Lithomarge.) Kaolinite. Hydrous-aluminum-ferric silicate.

Edge of Pontotoc, Llano County. Clear Creek, Burnet County (in quartz). High Point, Burnet County. North of Long Mountain, Llano County. San Fernando Creek, below Smoothing Iron Mountain, Llano County. King Mountains, Llano County. Near Field Creek, Llano County. Elm Creek, Mason County. Occurs as crusts on felsite-porphyries and granites, but is not usually abundant.

Cassiterite. Tin-iron oxide.

Ash Spring, Llano County. Of very doubtful occurrence here, as explained under the heading Tin, in Part II of this Report.

Carnelian. (Quartz var.)

Sandy Creek, Llano County. Pennington Creek, Llano County. Long Mountain, Llano County.

Chalcedony. (Quartz var.)

Northeast Barton's, on Hinton Creek, San Saba County. Cherty divide, between two branches of Deep Creek, San Saba County. Deep Creek region, San Saba County (cherty). Layers in chert and flint of the Deep Creek division of the San Saba series (Silurian).

Chalcopyrite. Copper-iron sulphide.

Miller mine, Llano County (with malachite and azurite). Mexican diggings, Babyhead Creek, Llano County. Elsewhere over the Central Mineral Region, but nowhere abundant.

Chalk. Calcium carbonate.

In part of the Cretaceous areas surrounding the region, particularly in the including promontory known as Mason Mountain, in Mason, Kimble, and Menard counties.

Chert. (Quartz var.) Silica.

In the Silurian Beds, upper part Burnet, Llano, Mason, San Saba, McCulloch, Kimble, and Gillespie counties; also in the Cretaceous Beds of Mason Mountain and other districts.

Chlorite. Hydrous-magnesium-ferrous-aluminum silicate.

About three and a half miles south of Enchanted Rock, Llano and Gillespie counties. Honey Creek, Llano County. Little Llano Creek Llano County, etc.

Chloropal. Hydrous-ferric-aluminum silicate.

Johnson's Creek, Llano County.

Clay Ironstone. Honey Creek, Llano County (Limonite).

Katemcy Creek, etc., McCulloch County, and other localities. Not of much importance as an ore in our district.

Columbite. Iron-manganese-columbate-tantalate.

Barringer Hill, Llano County (upon authority of Dr. Edgar Everhart, University of Texas, Austin, Texas).

Cyprine. Aluminum-calcium-ferro-magnesium silicate.

Babyhead region, Llano County (with idocrase and copper ore).

Cyrtolite. Hydrous-zirconium-cerium-ferrous silicate.

Barringer Hill, Llano County.

Dioryte.

Six miles above Lone Grove, Llano County. Near head of Cold Creek, Llano County. Honey Creek, at crossing of Menardville road, Mason County. West of Enchanted Rock, Gillespie County. Near Danser Peak, Llano County. Honey Creek, Llano County. Rather a loose generic term as here used.

Dolomite. Calcium-magnesium carbonate.

Very common as rock masses, occasionally crystalline, in the Silurian and Cambrian systems.

Enstatite. Magnesium silicate.

Head of Clear Creek, Burnet County. Base of Long Mountain on north, Llano County.

Epidosyte. (Epidote rock.)

Near Babyhead, Llano County. Miller's mine, Llano County. Johnson Creek, Llano County. Martin Creek, vicinity of Fly Gap, Mason County.

Epidote. Aluminum-ferric-calcium silicate.

One-half mile from Babyhead Postoffice, on Cherokee road, Llano County. Miller's mine, Llano County. Johnson Creek, Llano County. Fleming Postoffice, Mason County. Near Fly Gap, Mason County. Comanche Creek, three miles west of north from Mason, Mason County. Riley Mountains, near Click, Glen, and Sandy gaps (specimens and locality from James T. Barnett.) About one mile and a half from Llano, on branch of Oatman Creek, Llano County.

Fassaite. (Pyroxene var.)

From well on branch of Spring Creek, Burnet County.

Fergusonite. Ytrium-cerium-uranium-zirconium-tin-iron columbate.

Barringer Hill, Llano County.

Ferro-Calcite. Calcium-iron carbonate.

Silver Mine Hollow, Burnet County. Foot of Point Peak, Llano County. Near Lone Grove, Little Llano Creek, Llano County.

Fibrolite. Aluminum silicate.

Garnet diggings, Clear Creek, Burnet County. Head of Elm Creek, Mason County. Honey Creek, Llano County.

Flint. Silica.

In Silurian and Cretaceous limestones; somewhat common.

Fluorite. Calcium fluoride.

Barringer tract, Llano County.

Gadolinite. Ytrium-cerium-beryllium-ferrous-calcium silicate.

Barringer Hill, Llano County.

Galena. Lead sulphide.

Mexican diggings, Babyhead Creek, Llano County. Silver Mine Hollow, Beaver Creek, Burnet County. Mexican house. Babyhead Creek, Llano County. Cold Creek, Llano County. Caylor's diggings? Mason County. Beaver Creek, Llano County.

Garnet. Aluminum-iron-calcium, etc., silicate.

Babyhead region, Llano County. Near Wooten's, Elm Creek, Mason County. Garnet rock from Capt. McGehee's property, head of Little Llano Creek, Llano County. *See* Almandite, Andradite, Grossularite.

Gibbsite. Hydrous-aluminum-magnesium silicate.

Hinton Creek, San Saba County.

Glauconite. Hydrous-iron and potassium silicate.

Abundant as greensands of Cambrian period, and in grains in Cambrian green limestones.

Gold.

Very sparingly distributed. Occasionally in very small quantities in Llano and Gillespie counties.

Gœthite. Hydrous-ferric silicate.

Little Llano region, Llano County.

Granulyte.

Near Simpson's, Burnet County. High Point, Burnet County. Long Mountain region, Llano County. Yoakum Creek, Llano County.

Graphite. Carbon.

Foot of Long Mountain, in North Llano County. Below Lone Grove, Llano County. Public Pen Creek, Llano County. Cat Mountain region, Llano County. Menardville road, at Honey Creek crossing, Mason County. Headwaters of Honey Creek, Mason County. Near Caylor's diggings, Mason County. Morley's mine, Llano County. East Packsaddle Mountain, Llano County. Near Sandy Mountain, Llano County. In places north, south, east, and west of Llano City, Llano County.

Grey Copper. Antimony-arsenic-copper-iron-zinc-silver sulphide. *See* Tetrahedrite.

Grossularite. Lime-alumina garnet.

Vicinity of Fleming, Martin Creek, Mason County.

Gummite. Hydrous-uranium-calcium-phosphorus silicate.

Barringer Hill, Llano County; rare.

Hematite. Ferric oxide.

Mexican diggings, Babyhead, Llano County. Iron Mountain, Llano County. South of Pontotoc, Llano County. Nunnely's mine, Llano County. Divide between Spring and Clear creeks, Burnet County. Hooking Hollow, Burnet County. Hoover's Valley, Burnet County. King Mountains, Llano County. Long Mountain region, Llano County. Barringer Hill, Llano County. Sandy Creek, Llano County. Babyhead region, Llano County. Cold Creek, Llano County. East of Fleming, Mason County. Southeast Camp San Saba, Mason County. Caylor's diggings, Mason County. Near head of Bluff Creek, Mason County. James River region, Mason County. South of Tom Long's, above Gainesville, near Llano River, Llano County. Packsaddle Mountain, Llano County.

Hornblende. Aluminum-iron-magnesium-calcium silicate.

Lockhart Mountain, Llano County. Johnson Creek, Llano County. Martin Creek, vicinity of Fly Gap, Mason County.

Hyalite. (Opal). Silica.

Barringer Hill, Llano County. Gillespie County, near Enchanted Rock.

Hydrous Iron Ores. (Unclassified.)

Public Pen Creek region, Llano County. Elm Creek, Mason County. East of Cold Creek, above Bauman's, Llano County. Southeast of Camp San Saba, Mason County. Packsaddle region, Llano County.

Hypersthene. Ferrous-magnesium silicate.

Clear Creek, Burnet County (in orthoclase). Northern base of Long Mountain, Llano County (in orthoclase).

Idocrase. (*See* Vesuvianite). Syn.

Ilmenite. Iron and titanium oxide.

East of Cold Creek, above Bauman's, Llano County. North of Pontotoc, Mason County. Fly Gap, Mason County (in quartz). Barringer tract, Llano County.

Itabiryte. Hematite schist.

West of Kothman Gap, Martin Creek, near Fleming, Mason County.

Jasper. (Quartz). Silica.

Sandy Creek, Llano County. Pennington Creek, Llano County.

Jefferisite. Calcium-iron-magnesium-zinc-maganese silicate.

Mexican diggings, Babyhead Creek, Llano County. Johnson Creek, Llano county.

Kaolinite. Hydrous-aluminum silicate.

Pontotoc, Llano County (encrustation on quartz). Clear Creek, Burnet County (as quartz encrustatation). Silver Mine Hollow, Beaver Creek, Burnet County. Johnson Creek, Llano County (occurs with tourmaline). Iron Mountain, Llano County (in binary granite). King Mountains, Llano County (with serpentine). Enchanted Rock, Llano County.

Kielhauite. Titanium-calcium-aluminum-ferric-manganic silicate.

Kothman's Gap, near Fleming, Mason County.

Kerolite. Hydrous-magnesium silicate.

Iron Mountain, Llano County.

Labradorite. Aluminum-calcium-sodium-potassium-ferric-magnesium silicate.

Hoover's Valley, Burnet County.

Limnite? Hydrous-ferric oxide.

Long Mountain region, Llano County. Seven miles above Lone Grove, on Little Llano Creek, Llano County. Chaney's Diggings, Packsaddle Mountain, Llano County (perhaps not correctly placed here).

Limonite. Hydrous-ferric oxide.

Spring Creek region, Burnet County. High Point, Burnet County. Hoover Valley, Burnet County. North base of Long Mountain, Llano County. Seven miles above Lone Grove, Little Llano Creek, Llano County. East of Cold Creek, above Bauman's, Llano County. Near Pontotoc, Mason County. Near Castell, Llano County. Near Spiller mine, Fly Gap, Mason County. The divide between branches of Deep Creek and Wallace Creek, San Saba County. Near road from San Saba to Voca, three miles beyond crossing of Brady Creek, San Saba County. Northwest of Voca, McCulloch County. Near Camp San Saba, McCulloch County. South of Mason Mountain, Mason County. Near head of Little Bluff Creek, Mason County. Headwaters of Bluff Creek, Mason County. Near Caylor's diggings, Mason County. Ten Mile Creek, Mason County. James River region, Mason County. Six miles from Llano, near head of Silver Creek, Llano County. South of Garner Crossing of Llano River, Llano County. Honey Creek, Llano County. Chaney diggings, south of Packsaddle Mountain, Llano County. Nunnely's diggings, Gillespie County.

Lithomarge (Indurated Kaolinite). Hydrous-aluminum silicate.

High Point, Burnet County (thin clay shale).

Magnetite. Ferric and ferrous oxide.

Spring Creek, Burnet County. Clear Creek, Burnet County. Little Llano region, Llano County (small quantities). Near Yoakum Creek, Llano County (very little). Babyhead Mountain, Llano County. Iron Mountain, Llano County. Cold Creek, above Smoothing Iron Mountain, Llano County. Near Castell, Llano County. King Mountains, Llano County. Near Pontotoc, Mason County. West of Pontotoc, Mason County. Bode Peak region, Mason County. North of Fly Gap, Mason County. Köthman Gap, near Fleming, Mason County. Caylor's diggings, Mason County. Riley Mountains, Llano County. Near Sandy Mountain, Llano County.

Malachite. Hydrous-copper carbonate.

About three and one-half miles east of Valley Springs, Llano County. Babyhead region, Llano County. Yoakum Creek, Llano County. Houston and Texas Central Railroad lands, on Little Llano Creek, Llano County. Miller's mine, Llano County. Wolf and Pecan Creek waters, Llano County. One mile north of west of Koochville, on Comanche Creek, Mason County. Capt. McGehee's property, head of Little Llano Creek, Llano County.

Manganese Stain.

Near head of Martin Creek, Mason County, on quartz. Riley Mountains, Llano County. Area near Click, Glen, and Sandy gaps. End of Sharp Mountain, Llano County (stain on quartz).

Marcasite. Iron sulphide.

Occasionally in some localities given under pyrite.

Margarite. Hydrous-aluminum-calcium silicate.

West of Fly Gap, on road to Pontotoc, Mason County. Waters Creek, east of Riley Mountains, Llano County. Honey Creek, Llano County (in white quartz).

Margarodite. Hydrous mica.

Llano and Gillespie counties, in Archæan schists.

Martite. Isometric form of ferric oxide.

Barringer Hill, Llano County, south of Bluffton.

Melanite. *See* Garnet.

In float in Little Llano Creek, near Lone Grove, Llano County.

Menacconite. Ferric oxide with titanium replacing part of the iron. (*See* Ilmenite syn.)

Metagadolinite. (New mineral announced recently.)

Barringer Hill, Llano County (encrustation on gadolinite).

Mica. *See* Biotite and Muscovite.

Microcline. Aluminum-ferric-magnesian-calcium-sodium-potassium silicate.
Upper ford of Llano River, at Llano, Llano County.

Molybdenite. Molybdenum sulphide.
Barringer Hill, Llano County.

Molybdite. Molybdenum oxide.
Barringer Hill, Llano County.

Muscovite. Aluminum-potassium silicate.
Mexican diggings, Babyhead Mountain, Llano County. Little Llano Creek, below Lone Grove, Llano County. North of Lone Grove, Llano County. Johnson Creek, Llano County. Near Smoothing Iron Mountain, Llano County. North of Fly Gap, on road to Pontotoc, Mason County. Head of Rocky Creek, east of Riley Mountains, Llano County. Near Sandy Mountain Postoffice, Llano County. Many other localities.

Nivenite. (New mineral, discovered recently.)
Barringer Hill, Llano County.

Ochre. (*See* Limonite.)
Near Sutton's, Sand Creek, Llano County.

Oligoclase. Aluminum-calcium-sodium silicate.
Capitol granite quarries, Burnet County (in granite). Little Llano region, Llano County.

Opal. Silica.
Long Mountain, Llano County (in grains in felsite porphyry).

Orthoclase. Aluminum-potassium silicate.
Mexican diggings, Babyhead Mountain, Llano County. Capitol granite quarry, Burnet County. Headwaters Clear Creek, Burnet County. Spring Creek region, Burnet County (in granite). Shannon's quarries, Burnet County (in quartz). Near Niggerhead Mountain, in Burnet County. Clear Creek, near High Point, Burnet County. Hoover's Valley, Burnet County. Long Mountain region, Llano County. Barringer Hill, Llano County. Little Llano Creek, Llano County. Hickory Creek, Little Llano region, Llano County. Lockhart Mountain, Llano County. Upper ford of Llano River, Llano, Llano County. Parker's place, west of Llano, Llano County. Johnson Creek, Llano County. Streeruwitz mine, Llano County. Cold Creek region, Llano County. On Brady road, west of Bauman's, in Cold Creek region, Llano County. Twin Mountains, Llano County. Christian Schneider's place, near Castell, Llano County. North of Fly Gap, Mason County. Kothman's Water Gap, near Fleming, Mason County. West of Enchanted Rock, Mason County. Nunneley's mine, Llano County. East of Dancer Peak, Llano County.

Penninite. Hydrous-magnesian-aluminum-ferric-chromium silicate.
Mexican diggings, Babyhead Mountain, Llano County.

Phlogopite.
Barringer Hill, Llano County (upon authority of Dr. Edgar Everhart, University of Texas, Austin, Texas).

Psilomelane. Oxide of Manganese.
Head of Martin Creek, above Fleming, Mason County. Spiller mine, Mason County.

Pyrite. Iron sulphide.
Nunnely's mine, Llano County; Hoover's Valley, Llano County (both of the above brassy). Little Llano Creek valley, Llano County (yellow). Miller mine, Llano County (brassy). North of Pontotoc, Mason County. Six miles from Llano, on road to Click Gap, Llano County. South of Chaney's diggings, Packsaddle Mountain, Llano County.

Pyro-Aurite. Hydrous-ferric and magnesium oxide.
North of Pontotoc, Mason County. East of Camp San Saba, on San Saba and Camp San Saba road (little).

Pyrolusite. Manganic and manganous oxide.
Hocking Hollow, Clear Creek region, Burnet County. Spiller mine, Mason County.

Pyroxene. Iron-calcium-magnesium silicate.
Spring Creek region, Burnet County. Miller mine, Llano County.

Quartz. Silica.
Occurs white and smoky, amorphous and crystalline, twined and with inclusions, at Barringer Hill, Llano County. White and rose quartz in different parts of Llano County, amethystine in Gillespie County, and in various rock forms. A very abundant vein mineral in our region.

Saccharite. (Andesite var.)
Right bank of Little Llano Creek, below Lone Grove, Llano County.

Samarskite. Uranium-ferrous-yttrium-magnesium-calcium columbate and tungstate.
Barringer Hill, Llano County (upon authority of Dr. Edgar Everhart, University of Texas, Austin).

Serpentine. Hydrous-magnesium silicate.
King Mountains, Llano County. Near Long Mountain, Llano County. Gillespie County.

Silver.
In Galena and in Tetrahedrite and other copper ores in Llano County.

Steatite. *See* Talc.

Soapstone.

Mexican diggings, Babyhead, Llano County. King Mountains region, Llano County. Gillespie County.

Talc. Hydrous-magnesium silicate.

Mexican diggings, Babyhead region, Llano County. Pecan Creek, Llano County. Near Double Knobs, Mason County. Nunnely's mine, Llano County. Three and a half miles east of Enchanted Rock, close to the junction of two branches of Crab Apple Creek, Llano County.

Tengerite.

Barringer Hill, Llano County.

Tetrahedrite. Antimony-arsenic-copper-ferrous-zinc-silver sulphate.

Yoakum Hollow, Llano County. Packsaddle Mountain, Llano County.

Thorogummite. (New mineral, announced September, 1889, American Journal of Science, by Hidden.)

Barringer Hill, Llano County.

Tourmaline. Aluminum-magnesium-boro silicate.

Spring Creek, Burnet County. Hoover Valley, Burnet County. Upper crossing of Llano River, Llano, Llano County. Johnson Creek, Llano County. Public Pen Creek, Llano County. Martin Creek, near Fleming, Mason County. Riley Mountains, Llano County. Near Sharp Mountain, Llano County.

Travertine. Calcium carbonate.

Spring Creek, Burnet County. Two miles east of Smoothing Iron Mountain, on Brady road, Llano County. North of Sloan's house, on the San Saba River, San Saba County. West of Voca, at crossing of river, McCulloch County.

Tremolite. (Amphibole var.)

Lone Grove and Valley Springs road, one mile west of crossing of Pecan Creek. East base of Packsaddle Mountain, Llano County.

Tufa. *See* Travertine Calc-sinter, Calcite.

Turgite. Hydrous-ferric oxide.

Seven miles above Lone Grove, Little Llano Creek, Llano County. Hinton Creek, San Saba County. Seven miles from Mason, on Junction City road, Mason road, Mason County. Caylor's diggings, Mason County. James River, Mason County. Chaney's diggings, Packsaddle Mountain, Llano County.

Uralite? Aluminum-ferrous-magnesium-calcium silicate.

Houston and Texas Central Railroad lands, on Little Llano Creek, Llano County (stained with malachite.)

Uralorphite. *See* Allanite.

Babyhead, Llano County.

Vermiculite. Hydrous-magnesium-aluminum-ferrous silicate.
Mexican diggings, Babyhead Mountain, Llano County.

Vesuvianite. Aluminum-calcium-magnesium-iron silicate.
Garnet diggings, Burnet County. Barringer Hill, Llano County. Babyhead region, Llano County.

Wad. Maganese-hydrate.
Reported from Babyhead region. Cold Creek, Llano County.

Wochenite. Hydrous-aluminum-ferric silicate.
Yoakum Hollow district, Little Llano region, Llano County.

Yttrialite.
Barringer Hill, Llano County.

Zoisite. Aluminum-calcium-iron silicate.
Near Babyhead, Llano County.

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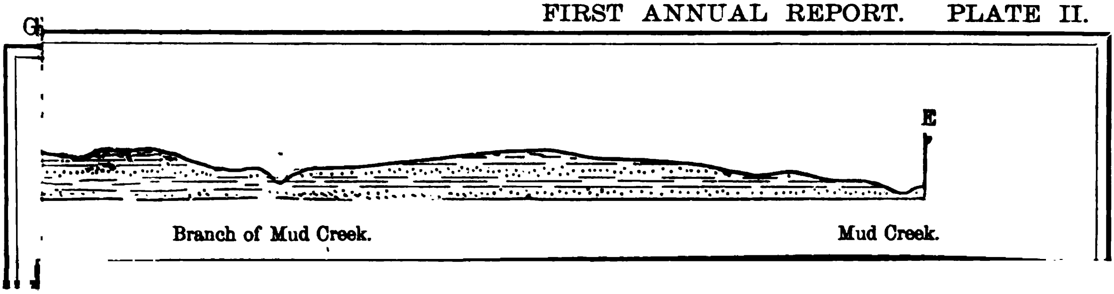
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Branch of Mud Creek.
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